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STEAM GENERATION
PIPE-FITTING TOOLS
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STEAM-HEATING PIPE SYSTEMS
EXHAUST AND VACUUM SYSTEMS
HOT-WATER HEATING SYSTEMS
HOT-WATER HEATING APPARATUS
CENTRAL-STATION HEATING

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PUBLISHERS' STATEMENT

The original manuscript for the majority of the sections in this volume, including Pipe-Fitting Practice, Steam-Heating Pipe Systems, and Exhaust and Vacuum Systems, was prepared by Mr. Thomas Barwick, Heating Engineer, New York, Member of the American Society of Heating and Ventilating Engineers. The paper on Central Station Heating was written by C. Wadsworth. In preparing the latter paper, we called on the trade for data, since this is a comparatively new field, and but little has been published on this subject. A number of manufacturers and contractors very kindly responded, and we especially desire to thank Mr. Charles R. Bishop, Secretary of the American District Steam Company, and Mr. C. C. Upham, General Manager of The New York Steam Company, for data presented for use in this textbook. The contents of this volume were prepared under the supervision of T. N. Thomson, Principal of the School of Plumbing, Heating, and Ventilation, assisted by the staff of the International Correspondence Schools.

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STEAM GENERATION

INTRODUCTION

EVAPORATION OF WATER

TRANSMISSION OF HEAT TO WATER

1. The heat generated by burning fuel in the furnace is transferred to the water in the boiler by radiation, by conduction, and by convection.

Radiation is the term used to signify the transfer of heat through space; *conduction* may be defined as signifying the transfer of heat through solids; *convection* is the transfer of heat through liquids or gases. The heat generated in the fire-pot or furnace is transmitted to the plates of the boiler principally by radiation. Convection also plays an important part in the transfer of heat as the hot gases pass from the fire through the flues and tubes and give up their heat to the boiler. Heat is transmitted through the plates and tubes by conduction and through the water in the boiler by convection.

2. The rate of transmission through the heating surfaces of a boiler is always proportional to the difference in temperature between the water and the hot gases, and it is also affected by differences in thickness of the metal, and by the form, character, cleanness, and relative position of the heating surfaces. Boilers are exactly the same in principle as radiators, being merely reversed in operation, and they are affected by similar conditions, in the same manner and degree.

In a radiator, the thickness of the metal is of small importance, mainly because the temperatures are low; but in a boiler, where the parts are exposed to intense heat, it is important that the metal should be as thin as practicable. If the metal is thick, one surface is likely to be much hotter than the other, and the inequality of the expansion causes stresses that tend to bulge or crack the plates. In a very thick plate, while the surface next to the water remains uninjured, the surface exposed to the hot fire is likely to be overheated and burned, and the plate thus becomes rapidly weakened. A thin steel tube, when full of water, may be exposed to the fiercest fire without injury, provided there is not an excessive internal pressure.

3. Air and other gases cannot absorb heat from one side of a metal plate as rapidly as hot water or steam will impart it to the opposite surface. The reverse of this fact is also true: Hot gases cannot impart heat to one side of a boiler plate as rapidly as water will absorb it from the opposite side. Therefore, it is an advantage to have the surfaces that are exposed to the hot gases larger in area than those in contact with the water. This is accomplished in water-tube boilers by putting the water inside the tubes, and exposing the outer and larger surfaces of the tubes to the fire.

4. The efficiency of a boiler is considerably affected by the manner in which the hot gases pass over its heating surface. If they flow in a direction parallel with the heating surface, much less heat will be transmitted through such surface than if they impinge on it at right angles or flow crosswise over it. The latter condition can be secured only in boilers that have the water inside of the tubes.

The water and hot gases should, as nearly as practicable, move in opposite directions, in order that the coolest part of the water may be exposed to the coolest gases, and that, as its temperature rises, it may be acted on by successively hotter gases. The greatest practicable temperature difference is thus maintained throughout the whole passage of the gases through the boiler, and consequently the maximum

amount of heat will be transmitted to the water. If the reverse arrangement were employed, the temperature difference would be greater near the fire than it would be elsewhere in the flues, and the total transmission of heat would be considerably less.

5. When the hot gases are passed through small tubes, as in locomotive and other fire-tube boilers, which types are used for large heating systems, they are cooled very rapidly, and if the tube is long, the cooling is likely to be so great that the farther end of the tube will be practically useless for making steam. In ordinary practice a boiler tube 3 inches in diameter should not exceed 12 feet in length, and smaller tubes should be made proportionally shorter. If the gases have been partly cooled by passing over other water-heating surfaces before entering the tubes, the length should be reduced accordingly. The aim should be to have the temperature of the gases at the moment they leave the tubes as near to the temperature of the steam as possible, but not to exceed it by more than 100°.

The length of a boiler tube that contains water, as in water-tube boilers, is limited by the rapidity and volume of the circulation. In general, very long or very slender tubes are objectionable, because of the difficulty of keeping them properly filled with water.

CIRCULATION OF WATER IN STEAM BOILERS

6. Objects.—Circulation is the name given to the motion of water under the influence of heat. The water nearest the source of heat becomes heated, expands, and thus becoming lighter, rises to the top. In consequence, cold water will flow toward the source of heat, become heated in turn, and rise. The rapidity with which the transfer of heat by convection will take place naturally depends on the rapidity of the circulation. If this is interfered with, the transfer of heat will be slow; on the other hand, if the circulation is free, the transfer of heat will be rapid. The objects of water circulation in steam boilers are as follows.

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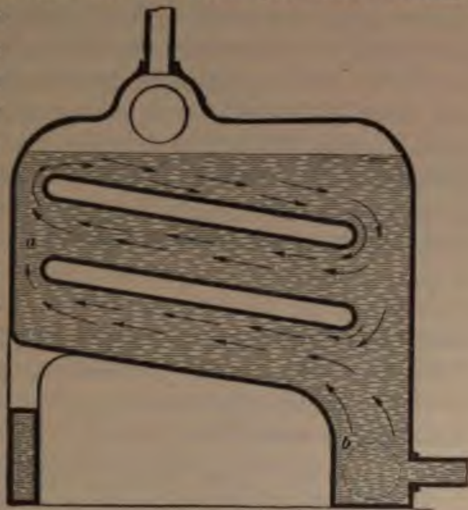

FIG. 2

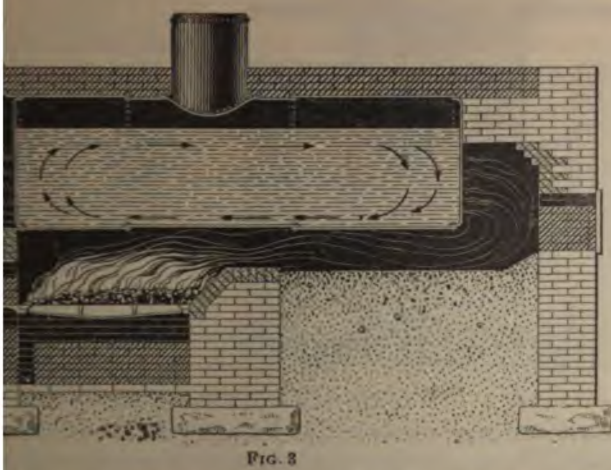

FIG. 3

he circulation of the water in the horizontal return-
boiler is shown in Fig. 3. The heated water rises

1. To keep the heating surfaces covered with water at all times, thus preventing any part from becoming overheated or burned, and securing regularity and steadiness in the generation of steam.

2. To equalize the temperature throughout all parts of the boiler, thus preventing unequal heating and consequently straining of the structure.

3. To maintain the greatest practicable difference of temperature between the water on one side of the metal and the hot gases on the other, thus insuring a good rate of heat absorption.

4. To sweep the heating surfaces clean of mud and other deposits, thus keeping them in the best condition for the transmission of heat.

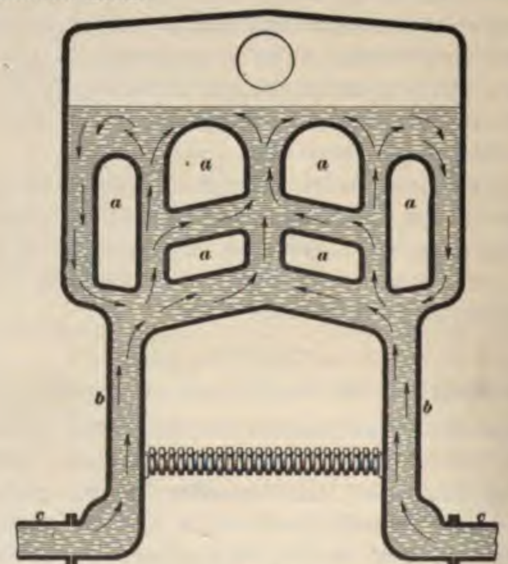

Fig. 1

7. Circulation in Different Types of Boilers.—The circulation of water in the common forms of sectional house-heating boilers, of which two types of sections are illustrated by Figs. 1 and 2, is indicated by the arrows. In the section shown by Fig. 1, the heated water rises vertically from the

surfaces directly above the fire and from the inner surfaces of the flues *a*, *a*, passing downwards in the side water legs. The relatively cool water of condensation from the radiators enters at the foot of the water legs *b*, *b* through return pipes or headers *c*, *c*, passing upwards as it is heated to points directly over the fire. The general direction of circulation in the section shown by Fig. 2 is practically the same

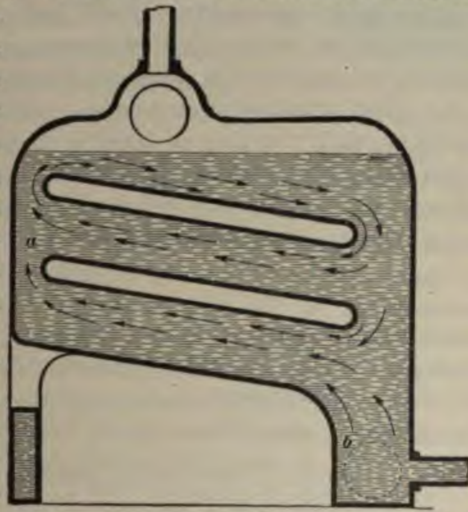

FIG. 2

as in Fig. 1, being upwards in the front waterway *a* and downwards in the water leg *b* at the rear.

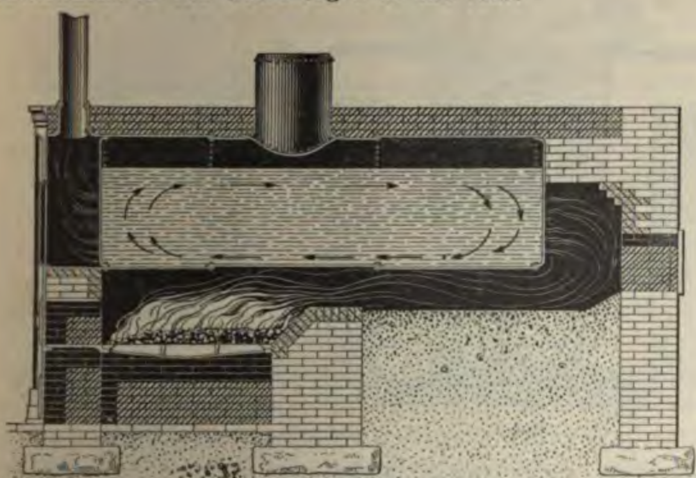

FIG. 3

8. The circulation of the water in the horizontal return-tubular boiler is shown in Fig. 3. The heated water rises

from the hottest part of the bottom of the shell, which is directly above the furnace, thus carrying the steam bubbles to the surface. The cooler water from the rear of the boiler flows in to take the place of that which has risen, and thus circulation is maintained in the general direction indicated by the arrows. It will be noticed that the horizontal direction of the circulation is contrary to that of the gases from the furnace. In cylindrical boilers the water is in a solid mass, and there is nothing to interfere with free circulation. In flue boilers and tubular boilers, however, the flues and tubes break up the body of water in such a manner as to cause numerous small currents that oppose the general direction of the circulation more or less. In order to have the circulation interfered with as little as possible, the tubes should not be spaced too closely.

9. It is one of the strong points of correctly designed water-tube boilers that the circulation is strong and uninterrupted by any opposing currents. This is accomplished by

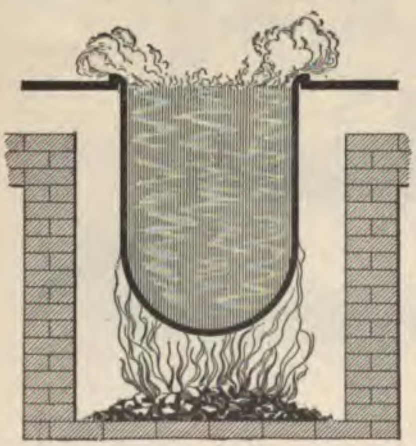

FIG. 4

FIG. 5

passing the water always in the same direction through the series of tubes. The difference between cylindrical shell boilers and water-tube boilers in this respect may be illustrated as follows: The cylindrical shell boiler with its large

volume of water may be compared to an ordinary kettle in the process of boiling (see Fig. 4). The water rises rapidly around the outer edges and flows downwards in the center. If, however, the fire is quickened, the upward and downward currents interfere with one another and the kettle boils over.

In principle the water-tube boiler is and should be identical with a **U** tube depending from a vessel filled with water, with the heat applied to one leg (see Fig. 5). The circulation is set up immediately and proceeds quietly, no matter how fierce the fire may be.

10. Imperfect Circulation.—If the flow of the ascending currents is impeded or obstructed by reason of insufficient passageways, so that the steam cannot freely escape from the water, there is danger of the water being lifted up or forced out of contact with the heating surfaces. This state of affairs may last from a few seconds to many minutes, according to the misconstruction of the boiler.

Steam being incapable of taking up heat as rapidly as the water, plates or tubes covered by steam instead of water are likely to be quickly overheated. When the water flows back on them they are cooled so suddenly that there is danger of cracking the metal, with possible serious results. The production of steam in such a boiler will be irregular and spasmodic, even with clean water; and if the water is inclined to produce foam, the trouble will be increased to a dangerous extent. The types of boilers that are most likely to exhibit this defect, and that are little used for ordinary domestic heating, are the return-tubular and the vertical-tubular boilers. The trouble is generally due to spacing the tubes too closely. Some designs of water-tube boilers are also faulty in this respect.

To secure a high degree of efficiency it is necessary that the parts of a boiler be so arranged that the mingled steam and water may flow upwards and away from the heating surfaces with entire freedom, and that the water, after parting with the steam bubbles, may flow back to the heating surfaces by a route which will avoid all interference with the ascending currents.

11. Aids to Circulation.—Various mechanical aids have been devised to assist the circulation within boilers. These consist mainly of *circulating tubes*, *baffle plates*, and special *return tubes*.

Fig. 6 shows the mode of applying a **circulating tube,** commonly known as a **Field tube,** to an ordinary drop or depending water tube. The drop tube A is attached to the boiler below the water-line and hangs down over the fire, thus being surrounded by hot gases. Steam is generated rapidly on its inner surface, and the mingled steam and water flow swiftly upwards. A return current of water flows downwards through the tube B, thus securing a rapid and positive circulation. The inner tube merely serves as a partition between the ascending and descending currents and prevents them from interfering. If it were absent, the steam bubbles would be likely to unite and form large bubbles that would completely fill the bore of the drop tube, and these would lift the water out of the tube in escaping. The water would then surge back into the hot tube and be again expelled by another rush of steam. The production of steam would thus be very spasmodic, and the tubes would soon be destroyed.

FIG. 6

The area of the circulating tube B should be about one-third that of the outer tube A. The space below the end of the inner tube should be about equal to the diameter of the outer tube.

Fig. 7 shows a construction suitable for drop tubes around the fire-pot that are heated mainly on one side. The tube is divided into two channels by means of a partition b, which extends nearly to the bottom end, as shown. The water ascends in the channel next the hot, or fire, side of the tube

and returns downwards in the other channel. At (*a*) is shown a section of the tube, taken on the line *x y*.

12. Baffle plates are partitions or deflecting plates that are set up at various points in a boiler for the general purpose of separating the currents that might otherwise conflict. Fig. 8 shows the manner of applying a baffle plate to a boiler having an internal firebox. The inner plate *a* is exposed to

FIG. 7

FIG. 8

the intense heat of the fire, while the outer plate *b* is exposed only to the atmosphere, and is comparatively cool. Steam is formed rapidly on the inner plate; consequently, there must be a lively circulation in the space between them; but the currents move in opposite directions and interfere to a serious extent. By introducing the baffle plate *c*, the space is divided into two channels, and interference is prevented.

The currents will move with greater rapidity than before, and the efficiency of the heating surface will be increased.

Baffle plates are applied in many other ways for the purpose of directing circulation currents, and are also used to restrain or confine the water at points where it boils too violently.

13. **Return tubes** are pipes that serve to convey the water from the upper part of the boiler to the lower part. They are generally made large in diameter, and are placed so that they will not receive very much heat; sometimes they are located outside of the walls of the combustion chamber, and are used principally on water-tube boilers such as are employed in heating large buildings and in furnishing power for lighting, etc.

FUELS

KINDS OF FUEL

14. The fuels used in the generation of steam and for heating purposes are chiefly coal, coke, wood, the mineral oils (such as petroleum), and natural gas. Other fuels, such as the waste gases from blast furnaces, straw, bagasse (refuse from sugar cane), dried tan bark, green slabs, sawdust, peat, etc. are also used, but rarely if ever for heating purposes. All these fuels are composed of either carbon alone or carbon in combination with hydrogen, oxygen, and non-combustible substances.

15. A prominent authority, Mr. William Kent, divides coal into four leading varieties, as follows:

1. *Anthracite coal*, which contains from 92.31 to 100 per cent. of fixed carbon and from 0 to 7.69 per cent. of volatile hydrocarbons.

2. *Semianthracite coal*, which contains from 87.5 to 92.31 per cent. of fixed carbon and from 7.69 to 12.5 per cent. of volatile hydrocarbons.

3. *Semibituminous coal*, which contains from 75 to 87.5 per cent. of fixed carbon and from 12.5 to 25 per cent. of volatile hydrocarbons.

4. *Bituminous coal*, which contains from 0 to 75 per cent. of fixed carbon and from 25 to 100 per cent. of volatile hydrocarbons.

16. Anthracite coal is rather hard to ignite and requires a strong draft to burn it. It is quite hard and shiny; it is black in color. It burns with almost no smoke; this fact gives it a peculiar value in places where smoke is objectionable.

17. Anthracite coal is known to the trade by different names, according to the size into which the lumps are broken. These names, with the generally accepted dimensions of the screens over and through which the lumps of coal will pass, are given in the following:

Culm passes through $\frac{3}{16}$-inch round mesh.

Rice passes over $\frac{3}{16}$-inch mesh and through $\frac{3}{8}$-inch square mesh.

Buckwheat passes over $\frac{3}{8}$-inch mesh and through $\frac{1}{2}$-inch square mesh.

Pea passes over $\frac{1}{2}$-inch mesh and through $\frac{3}{4}$-inch square mesh.

Chestnut passes over $\frac{3}{4}$-inch mesh and through $1\frac{3}{8}$-inch square mesh.

Stove passes over $1\frac{3}{8}$-inch mesh and through 2-inch square mesh.

Egg passes over 2-inch mesh and through $2\frac{3}{4}$-inch square mesh.

Broken passes over $2\frac{3}{4}$-inch mesh and through $3\frac{1}{2}$-inch square mesh.

Steamboat passes over $3\frac{1}{2}$-inch mesh and out of screen.

Lump passes over bars set from $3\frac{1}{2}$ to 5 inches apart.

18. Semianthracite coal kindles easily and burns more freely that the true anthracite coal. Hence, it is highly esteemed as a fuel. It crumbles readily and may be distinguished from anthracite coal by the fact that when just fractured it will soil the hand, while anthracite will not do so. It burns with very little smoke. Semianthracite coal is broken into different sizes for the market; these sizes are

the same and are known by the same trade names as the corresponding sizes of anthracite coal.

19. Semibituminous coal differs from semianthracite coal only in having a smaller percentage of fixed carbon and more volatile hydrocarbons. Its physical properties are practically the same, and since it burns without the smoke and soot emitted by bituminous coal, it is a valuable steam fuel.

20. Bituminous coal may be broadly divided into three general classes:

1. *Caking coal*, which name is given to coal that, when burned in the furnace, swells and fuses together, forming a spongy mass that may cover the whole surface of the grate. This coal is difficult to burn, since the fusing prevents the air passing freely through the bed of burning fuel; when caking coal is burned, the spongy mass must frequently be broken up with the slice bar, in order to admit the air needed for its combustion.

2. *Free-burning coal*, which is often called non-caking coal from the fact that it has no tendency to fuse together when burned in a furnace.

3. *Cannel coal* is a grade of bituminous coal that is very rich in hydrocarbons. The large percentage of volatile matter makes it valuable for gas making, but it is little used for the generation of steam, except near the places where it is mined.

21. Bituminous and semibituminous coals are known to the trade by the following names:

Lump coal, which includes all coal passing over screen bars $1\frac{1}{2}$ inches apart.

Nut coal, which passes over bars $\frac{3}{4}$ inch apart and through bars $1\frac{1}{2}$ inches apart.

Pea coal, which passes over bars $\frac{3}{8}$ inch apart and through bars $\frac{3}{4}$ inch apart.

Slack, which includes all coal passing through bars $\frac{3}{8}$ inch apart.

22. Lignite, according to the classification, comes under the general head of bituminous coal. Properly

speaking, it occupies a position between peat and bituminous coal, being probably of a later origin than the latter. It has an uneven fracture and a dull luster. Its value as a steam fuel is limited, since it will easily break in transportation. Exposure to the weather causes it to absorb moisture rapidly; it will then crumble quite readily. It is non-caking and yields but a moderate heat, and is in this respect inferior to even the poorer grades of bituminous coal.

23. Coke is made from bituminous coal by driving off its volatile constituents. It is used chiefly for metallurgical purposes, though it is a valuable fuel for steam purposes.

24. Wood is much used in localities where it is abundant. The effective heating value of different kinds of wood differs but very little.

25. Bagasse is the refuse left after the juice has been extracted from sugar cane by means of the mill rolls. It is used to some extent in tropical and semitropical countries. Naturally, its use is limited to the places where the sugar cane is grown.

Dried tan bark, straw, slabs, and sawdust being refuse, their use is local and usually confined to tanneries, planing mills, sawmills, and threshing outfits.

26. Petroleum is occasionally used as a fuel, and, as such, possesses some advantages, among which are the ease of lighting and controlling the fire, the uniformity of combustion, and the economy in labor. Its disadvantages are: danger of explosion, loss of fuel by evaporation, and high price in comparison with coal. The Standard Oil Company estimates that 173 gallons of petroleum is equal to 1 long ton (2,240 pounds) of coal, allowing for all savings incidental to its use.

27. Natural gas is abundant in parts of Ohio and Pennsylvania, and is there often used as a fuel for the generation of steam. On an average, 30,000 cubic feet of natural gas is the equivalent of 1 ton of coal.

28. Waste gases from the furnaces of rolling mills and from blast furnaces are extensively used. Naturally, their use is limited to the places where they are produced.

29. Peat may be classified as occupying an intermediate position between wood and coal. When first cut, it is totally unfit for fuel, since it contains from 75 to 80 per cent. of water. When dried, it makes a fairly good fuel.

30. The Babcock & Wilcox Company state that on the average 1 pound of good bituminous coal may be considered as the equivalent of 2 pounds of dry peat, $2\frac{1}{2}$ pounds of dry wood, $2\frac{1}{2}$ to 3 pounds of dry tan bark or sun-dried bagasse, 3 pounds of cotton stalks, $3\frac{3}{4}$ pounds of straw, 6 pounds of wet bagasse, and from 6 to 8 pounds of wet tan bark.

HEATING VALUE OF FUELS

31. The heating value of a fuel is usually measured by the number of British thermal units (abbreviated to B. T. U.) given out by the complete combustion of 1 pound of the fuel, a British thermal unit being the amount of heat required to raise 1 pound of distilled water from 62° to 63° F. The principal constituents of coal are carbon and hydrogen, whose chemical combination with the oxygen of the air is accompanied by the production of heat. Complete or perfect combustion in a commercially practical sense has not been attained, although results closely approaching it have been obtained with natural gas and oils. Oxygen is the supporter of combustion, the rapidity of which depends on the amount of oxygen supplied in a given time to a fixed amount of fuel. Various grades of coal contain different percentages of carbon and therefore have different heating values. The average heating values, per pound, of commonly used fuels are:

Fuel	British Thermal Units
Coal, anthracite	13,500
Coal, bituminous	14,000
Petroleum	20,500
Wood	7,400

32. The full heating value of a fuel is not realized in practice. For heating purposes fuel is burned at a much lower rate than in power boilers, and for house-heating work, with an ordinarily good grade of coal, between 8,000 and 9,000 British thermal units per pound of coal will be absorbed by the water at the ordinary combustion rate of from 4 to 8 pounds of coal per square foot of grate surface per hour. In power boilers, the combustion rate is usually higher than in heating boilers, and an average of 11,000 British thermal units per pound of coal are absorbed by the water. The reason for the difference in the amount of heat absorbed per pound of coal in heating and power boilers is found primarily in the different conditions of service. Heating boilers usually run a large part of the time under a dampened fire, in consequence of which there is an incomplete combustion of the coal during part of the time; power boilers, on the other hand, generate steam with a bright fire and very little incomplete combustion, an attendant being present most of the time to see that the coal is burned to the best advantage.

Assuming that in a heating boiler 8,000 British thermal units per pound of coal, as ordinarily burned, will be absorbed by the water and burning from 4 to 6 pounds of coal per hour per square foot of grate surface, then from 32,000 to 48,000 British thermal units per hour would be absorbed for every square foot of grate surface. Since 1 square foot of direct steam radiating surface requires an average of 300 British thermal units per hour, 1 square foot of grate surface may be considered to be able to supply steam for from 106 to 160 square feet of radiating surface.

It is apparent that by increasing the rate of combustion the same heating boiler will supply steam for a proportionally increased amount of radiation, but to do so without making a corresponding increase in the amount of heating surface, and thus forcing the heater beyond the capacity for which it was intended by the manufacturer, introduces a serious loss in heat, which passes up the chimney in the escaping gases.

BOILER INSTALLATION AND MANAGEMENT

BOILER INSTALLATION

CHIMNEYS

33. General Considerations.—The action of gravity in forcing a column of warm gases within a chimney up and out by the excess of weight of an exactly similar column of the cold air outside the chimney is called **draft.** Proper chimney draft is absolutely necessary in order to supply the requisite amount of air for supporting combustion, the draft forcing the air through the fuel into the furnace. The intensity of the draft determines the rate of combustion of the fuel used, which varies from 4 to 20 pounds of coal per hour per square foot of grate.

To obtain a good draft it is necessary that the chimney be well built and sufficiently high to be above all surrounding obstructions, the highest efficiency being obtained when the internal cross-sectional area of the chimney is such as to readily take care of the maximum amount of work that the chimney may be called on to perform.

Chimney draft is affected by so many varying conditions that no absolutely reliable rules can be given for proportioning chimneys to give a certain desired draft pressure, since the pressure required to force the air through the fire and to overcome the frictional resistances of the smoke flues and chimney to the passage of the gases cannot be determined beforehand with any degree of accuracy from purely theoretical considerations. For this reason, the rules given for chimney proportions are based on successful practice rather than on pure theory.

34. Capacity of Chimneys.—The velocity with which the heated gases travel upwards, and hence the chimney capacity, becomes greater, other things being equal, as the difference between the inside and outside temperatures increases. It also increases with the height of the chimney, but this is true only within certain limits in chimneys exposed to the weather, because the higher the chimney the greater the loss of heat by radiation from its external surface, which counteracts or neutralizes the effect of an increase of height. The velocity should be sufficient to insure a steady outpour of the escaping gases against the influence of winds, and yet not great enough to cause a waste of fuel. Satisfactory results in house heating are obtained when the velocity of the gases in the chimney is approximately 5 feet per second.

The form or shape of a chimney has a pronounced effect on its capacity. A round chimney has a greater capacity for a given area than a square one, the frictional resistance to the flow of the waste gases of combustion in the latter being greater than that in the former, while a narrow rectangular flue offers even greater frictional resistance to the passage of the gases. Calculations based on the requisite area of a round chimney, a form seldom used in small buildings because of the difficulty of construction, as well as lack of space, should therefore be corrected to allow for the greater resistance offered by rectangular flues.

Loss of efficiency due to friction may be reduced to a minimum by making the inside of the chimney as smooth as possible. For house-heating work terra-cotta flues can be used to better advantage than the ordinary brick flues, or cast-iron pipes may be built into the walls, with ventilating spaces around the pipes for discharging the foul air from the various rooms.

In large office and other public buildings the chimney is frequently a riveted circular wrought-iron or steel stack enclosed in brickwork, with an insulating air space between the latter and the outer surface of the stack to prevent loss of efficiency due to radiation of heat therefrom and also to provide for expansion and contraction of the stack. Iron

stacks are generally the same size throughout their length. the lining used in stacks exposed to the weather, however, is gradually made thinner toward the top.

A round chimney is better than a square one, and a straight flue is better than a tapering one. If the flue is tapering, the area for calculation is measured at its smallest section. The flue through which the gases pass from the boilers to the chimney should have an area equal to, or a little larger than, the area of the chimney. Abrupt turns in the flue or contractions of its area should be carefully avoided, as they greatly retard the flow of the gases. Where one chimney serves several boilers, the branch flue from each furnace to the main flue must be somewhat larger that its proportionate part of the area of the main flue.

When the chimney is built into the more or less inflammable walls of the house it should be of generous internal proportions in order to avoid overheating of the chimney and the consequent danger from fire.

35. Size of Chimneys for Steam-Heating Boilers. The required dimensions of chimneys designed to meet known or assumed conditions may be approximately determined by the rules given. Mr. William Kent, a recognized authority on chimney design, states: "The retarding of the ascending gases by friction may be considered as equivalent to a diminution of the area of the chimney, or to a lining of the chimney by a layer of gas that has no velocity. The thickness of the lining is assumed to be 2 inches for all chimneys."

The actual area diminished by the area of a layer of gas 2 inches thick and extending clear around the chimney is called the **effective area** of the chimney.

36. With steam-heating boilers the effective chimney area is usually based on the total number of square feet of direct heat radiating surface in the radiators supplied by the boilers. It is customary to speak of "radiation" instead of using the expression "heat-radiating surface."

Rule.—*To find the effective area of a round and fully exposed chimney, in square feet, multiply .003 by the number of square*

feet of direct radiation and divide the product by the square root of the height of the chimney in feet. For a rectangular chimney multiply the quotient by 1.1.

Or, $$A_e = \frac{.003\ R}{\sqrt{H}} \text{ for round chimneys, and}$$

$$A_e = 1.1 \times \frac{.003\ R}{\sqrt{H}} \text{ for rectangular chimneys}$$

where A_e = effective area, in square feet;
R = radiation, in square feet;
H = height of chimney, in feet.

If one-third of a round or rectangular chimney is exposed, 25 per cent. less area than given by the rule will be sufficient; or, if the chimney is carried up through the house, a reduction of $33\frac{1}{3}$ per cent. in area is permissible.

EXAMPLE.—If the amount of direct radiation is 3,000 square feet and the height of the chimney is 60 feet, what should be the effective area of the chimney, which is entirely exposed to the weather, and round?

SOLUTION.—Applying the formula just given,

$$A_e = \frac{.003 \times 3{,}000}{\sqrt{60}} = 1.16 \text{ sq. ft.} \quad \text{Ans.}$$

37. In designing a chimney it is more convenient to calculate the diameter of a round chimney, or the length of the side of a square chimney, directly from the effective area given by the rule in Art. **36,** than to compute first the actual area required and from this the dimensions.

Rule I.—*To find the dimension of the side of a square chimney, in inches, of the requisite area, multiply 12 by the square root of the effective area in square feet and add 4 to the product.*

Or, $$l = 12\sqrt{A_e} + 4$$

where l = length of side, in inches;
A_e = effective area, in square feet.

EXAMPLE 1.—If a chimney is to have an effective area of 1.157 square feet, and is to be square, what should be the inside length of the sides?

SOLUTION.—Applying rule I,

$$l = 12 \times \sqrt{1.157} + 4 = 16.9 \text{ in.} \quad \text{Ans.}$$

Rule II.—*To find the inside diameter, in inches, of a round chimney of the requisite area, multiply 13.54 by the square root of the effective area, in square feet, and add 4 to the product.*

Or, $$d = 13.54\sqrt{A_e} + 4$$

where d = diameter, in inches;

A_e = effective area, in square feet.

EXAMPLE 2.—What should be the actual inside diameter of a chimney intended to have an effective area of 1.157 square feet?

SOLUTION.—Applying rule II,

$$d = 13.54 \times \sqrt{1.157} + 4 = 18.57 \text{ in. Ans.}$$

38. The effective area and diameter, or length of side, of a chimney for a steam-heating installation having been computed, the necessary height may be found by the following rule:

Rule.—*To find the required height, in feet, to produce a good draft in a chimney of given size, multiply .003 by the number of square feet of direct radiation, divide the product by the effective area of the chimney, in square feet, and square the quotient.*

Or, $$H = \left(\frac{.003\,R}{A_e}\right)^2$$

where H = height of chimney, in feet;

R = radiation, in square feet;

A_e = effective area, in square feet.

EXAMPLE.—The amount of direct radiating surface being 7,000 square feet and the effective area of chimney 2.5 square feet, what should be the height of the chimney to provide satisfactory draft?

SOLUTION.—Applying the rule just given,

$$H = \left(\frac{.003 \times 7{,}000}{2.5}\right)^2 = 70 \text{ ft. Ans.}$$

39. For convenience, Table I has been calculated, by the rule given in Art. **36** and rule I in Art **37**, for different heights of chimney and for different amounts of direct radiation. The table gives the actual length of the side of square chimneys in inches. In order to find the diameter, in inches, of a corresponding round chimney, the length of the side of

a square chimney given in the table should be multiplied by 1.13. In the table the approximate horsepower of the boiler is given in the second column; the values there given are based on the assumption that a boiler of 1 horsepower will furnish sufficient steam for 100 square feet of direct radiating surface.

TABLE I

SIZE OF SQUARE CHIMNEYS FOR STEAM HEATING

Square Feet of Direct Steam Radiation	Approximate Equivalent in Horsepower	Height of Chimney, in Feet								
		25	30	40	50	60	80	100	120	150
		Length of Side, in Inches								
100	1	6.9	6.8	6.6	6.5	6.4	6.2	6.1	6.0	5.9
300	3	9.1	8.9	8.6	8.3	8.1	7.8	7.6	7.4	7.3
500	5	10.6	10.3	9.8	9.5	9.3	8.9	8.6	8.4	8.2
700	7	11.8	11.4	10.9	10.5	10.3	9.8	9.5	9.3	9.0
1,000	10	13.3	12.9	12.3	11.8	11.5	11.0	10.6	10.3	9.9
1,500	15	15.5	14.9	14.1	13.6	13.1	12.5	12.0	11.7	11.3
2,000	20	17.1	16.4	15.7	15.1	14.6	13.8	13.3	12.9	12.4
3,000	30	20.1	19.3	18.3	17.5	16.9	16.1	15.4	14.9	14.3
4,000	40	22.6	21.8	20.5	19.6	18.9	17.9	17.0	16.6	15.9
5,000	50	24.8	23.9	22.4	21.5	20.7	19.6	18.7	18.0	17.3
6,000	60	26.8	25.7	24.2	23.1	22.3	20.2	20.1	19.4	18.5
7,000	70	28.6	27.5	25.9	24.7	23.8	22.4	21.4	20.6	19.7
8,000	80	30.3	29.1	27.4	26.1	25.1	23.6	22.6	21.8	20.8
9,000	90	31.9	30.6	28.8	27.1	26.4	24.9	23.7	22.8	21.8
10,000	100	33.4	32.1	30.1	28.7	27.6	26.0	24.8	23.9	22.8
12,500	125	36.9	35.4	33.2	31.6	30.4	28.6	27.2	26.2	25.0
15,000	150	40.0	38.4	36.0	34.3	32.9	30.9	29.5	28.3	27.0

40. Size of Chimneys for Power Boilers.—The capacity of a chimney for a steam power plant, expressed in the horsepower of the engine, or engines supplied with steam by the boiler or boilers served by the chimney, may be found by Mr. William Kent's rule, given below. This rule is based on the assumption that the engines supplied by the boilers will develop a horsepower with a coal consumption of 5 pounds per hour. In order to apply the rule

for the capacity of the chimney, the effective area must first be calculated. This may be done by the following rule:

Rule I.—*To find the effective area of a chimney, multiply .6 by the square root of the actual area, in square feet, and subtract the product from the actual area.*

Or, $$A_e = A - .6\sqrt{A}$$

where A_e = effective area, in square feet;
A = actual area, in square feet.

EXAMPLE 1.—The actual area of a chimney being 1.98 square feet, what is its effective area?

SOLUTION.—Applying rule I,

$$A_e = 1.98 - .6\sqrt{1.98} = 1.14 \text{ sq. ft. Ans.}$$

Rule II.—*To find the horsepower of a plant for which a given chimney will be sufficiently large, multiply 3.33 by the square root of the height of the chimney, and by its effective area.*

Or, $$P = 3.33\sqrt{H} \times A_e$$

where P = horsepower of plant;
H = height of chimney, in feet;
A_e = effective area of chimney, in square feet.

EXAMPLE 2.—A chimney 120 feet high has an effective area of 1.7 square feet. For what size of power plant, expressed in engine horsepower, would the chimney be large enough?

SOLUTION.—Applying rule II,

$$P = 3.33\sqrt{120} \times 1.7 = 62. \text{ Ans.}$$

41. Makers of power boilers usually recommend such a diameter and height of chimney for their boilers as their own experience has led them to believe will prove satisfactory. Since boilermakers differ in their experiences, their recommendations as to chimney sizes also differ somewhat. The practice of two prominent boiler manufacturing establishments is given in Table II, the chimney proportions given for horizontal return-tubular boilers being those recommended by the Phœnix Iron Works Company, Meadville, Pennsylvania, and the chimney proportions given for locomotive type

TABLE II

SIZE OF ROUND CHIMNEYS FOR POWER BOILERS

Horsepower of Boilers	Return-Tubular Boiler				Locomotive or Firebox Boilers					
	Diameter of Boiler Inches	Length of Boiler Feet	Chimney Proportions: Diameter of Chimney Inches	Chimney Proportions: Height of Chimney Feet	Diameter of Boiler Inches	Length of Firebox Inches	Width of Firebox Inches	Length of Tubes Inches	Chimney Proportions: Diameter of Chimney Inches	Chimney Proportions: Height of Chimney Feet
10	30	8	14	28						
15	36	8	16	28	32	36	26	84	16	24
20	36	10	16	36	34	42	28	90	16	24
25	42	10	18	36	36	48	30	96	18	24
30	42	12	18	40	40	48	34	96	20	24
35	44	12	20	40						
40	44	14	20	50	42	48	36	120	20	30
45	48	14	22	50						
50	54	12	24	40	44	54	38	132	22	36
60	54	15	24	60						
60	60	12	28	40	48	60	42	138	24	40
70	60	14	28	50	54	60	48	144	24	40
80	60	16	28	60	56	60	50	144	26	40
100	66	16	30	60	60	60	54	168	30	46
115	66	18	30	70						
125	72	16	34	60	66	60	60	180	32	50
150	72	18	34	70	66	66	60	192	32	55
175	78	18	38	70						
200	78	20	38	80						

firebox boilers being those recommended by the E. Keeler Company, Williamsport, Pennsylvania. The diameters given are for round sheet-steel chimneys, and are inside diameters. The chimney sizes given are for single boilers.

EXAMPLES FOR PRACTICE

1. If a chimney is 40 feet high and the building contains 1,200 square feet of radiation, what should be the effective area, if the chimney is square and entirely exposed to the weather? Ans. .63 sq. ft.

2. What is the length of the side of the chimney given in example 1? Ans. 13.5 in., nearly

3. Suppose the effective area of a round chimney is .63 square feet, what should its actual internal diameter be? Ans. 14.7 in., nearly

4. If the actual area of a chimney is 4 square feet, what is the effective area? Ans. 2.8 sq. ft.

5. If a chimney 64 feet high has an effective area of 2.4 square feet, what is the horsepower for which it will be sufficient? Ans. 64 H. P.

HEATING SURFACE

42. Definition.—That portion of the boiler surface exposed to the action of the flames and hot gases, is called the **heating surface.** The actual heating surface of a boiler includes all parts that have water on one side of the metal, and gas having a higher temperature than the water on the other. Parts that are covered with steam instead of water on one side have little value in increasing the steam-generating capacity of the boiler.

43. Efficiency and Arrangement of Heating Surface.—The ability of the heating surface to abstract heat from the gases of combustion depends largely on its location in the boiler and on the character of its contact with the gases. The best heating surface is a flat horizontal plate above the fire, as, for example, the crown sheet of the locomotive type of boiler. The lower shell of a horizontal tubular boiler is not quite as efficient on account of its curvature. A vertical plate is about one-half as efficient as a horizontal plate above the fire, and a horizontal plate below the fire is nearly worthless. When the gases pass through

tubes, as in tubular horizontal and vertical boilers, the tubes give up more heat to the water when horizontal than when vertical, and the first 3 or 4 feet of the tube are very much more efficient than the end near the smokebox. Further, in a horizontal tubular boiler, the water abstracts much more heat from the upper tubes than from those near the bottom of the shell. In computing the heating surface of a boiler, no account is taken of the difference of efficiency. It is a point, however, that should be carefully considered in the design of boilers.

44. The heating surface of domestic heating boilers—that is, the surface that receives and, by conduction, transmits to the water the heat generated by the combustion of the fuel—varies widely in character and disposition in different heating boilers. The portion of the heating surface close to the fire, under the direct influence of the radiant heat, is much more effective in generating steam than that portion of the so-called **indirect heating surface**, which is heated only by contact with the hot gases, the relatively great amount of indirect heating surface found in the majority of domestic heating boilers being provided in order to utilize as much of the available heat as possible.

45. The heating surface of tubular boilers includes the portions of the shell below the line of brickwork, the exposed heads of the shell, and the interior surface of the tubes. In the case of a water-tube boiler, the heating surface comprises the portion of the shell below the brickwork, the outer surface of headers, and outer surface of tubes. Since the greatest part of the heating surface of tubular boilers is furnished by the tubes, particular attention must be paid to their size and arrangement. The length of the tubes should be about 50 diameters for bituminous coal and 60 diameters for anthracite coal; these two proportions represent good modern practice. The tubes of horizontal boilers should be arranged in horizontal and vertical rows, with a horizontal spacing of from $1\frac{1}{3}$ to $1\frac{1}{2}$ times the tube diameter, preferably the latter. The vertical spacing may be somewhat less. The upper row of tubes should not be any higher than two-thirds

of the diameter of the boiler from the bottom in order to leave ample steam room on the top. The sizes of tubes used in ordinary practice with horizontal return-tubular boilers are as follows: For boilers between 36 and 48 inches diameter, 3-inch tubes; from 48 to 60 inches diameter, $3\frac{1}{2}$-inch tubes; from 60 to 72 inches diameter, 4-inch tubes.

It is common practice to divide the tubes into two nests with a large central water space, as it is thought that such an arrangement permits the water to rise in the central space and descend on the outside of the nests next to the shell. There is little reason to doubt that the central water space will cause such circulation when the tubes are packed closely together. Many authorities, however, hold that much better results can be obtained by a wider and uniform horizontal spacing of the tubes, thus insuring a freer circulation between each row of tubes.

A space of at least 3 inches should be left between the tubes and the shell; the bottom row of tubes should be at a sufficient distance from the bottom of the shell to allow a large body of water to rest directly on the sheets exposed to the fire. This insures good circulation and facilitates examination, cleaning, and repairs.

46. Since in tubular boilers the products of combustion must pass through the tubes or flues, their combined cross-sectional area (usually called the **tube area**) must be large enough to allow the volume of heated gases to pass through them without interfering with the draft, and be small enough to retard the flow of gases sufficiently to allow them to part with the greater part of their heat. The average practice is to make the combined cross-sectional area of the tubes or flues equal to from one-ninth to one-eighth of the grate surface for anthracite coal, and from one-seventh to one-sixth of the grate surface for bituminous coal.

47. Tubes for steam boilers are made of charcoal iron or soft steel and are lap-welded or solid drawn. When tubes exceed 6 inches in external diameter, they are commonly spoken of as **flues.** Unlike pipes, the sizes of tubes for

TABLE III

STANDARD SIZES OF BOILER TUBES

Diameter Inches	Thickness Inch	Wire Gauge Number	Transverse Internal Area Square Inches	Length of Tube per Square Foot of Internal Surface Feet
1	.072	15	.575	4.462
$1\frac{1}{4}$	.072	15	.961	3.453
$1\frac{1}{2}$	.083	14	1.398	2.863
$1\frac{3}{4}$	.095	13	1.911	2.448
2	.095	13	2.573	2.110
$2\frac{1}{4}$	.095	13	3.333	1.854
$2\frac{1}{2}$	.109	12	4.090	1.674
$2\frac{3}{4}$	.109	12	5.035	1.509
3	.109	12	6.079	1.373
$3\frac{1}{4}$	.120	11	7.116	1.260
$3\frac{1}{2}$	.120	11	8.347	1.172
$3\frac{3}{4}$	.120	11	9.676	1.088
4	.134	10	10.939	1.024
$4\frac{1}{2}$	.134	10	14.066	.902
5	.148	9	17.379	.812
6	.165	8	25.249	.673
7	.165	8	34.942	.573
8	.165	8	46.204	.498
9	.180	7	58.629	.442
10	.203	6	72.292	.398
11	.220	5	87.583	.362
12	.229	$4\frac{1}{2}$	104.629	.330
13	.238	4	123.190	.305
14	.248	$3\frac{1}{2}$	143.224	.283
15	.259	3	164.720	.264
16	.284	2	187.040	.248

boiler work are designated by their external diameter, which is the *actual* diameter and not the nominal diameter, as in case of pipes used for conveying fluids. The standard dimensions of the tubes most commonly used are given in Table III.

Boiler tubes up to and including 6 inches in external diameter may be allowed a working pressure of 225 pounds per square inch, if made of the thickness given in the table. Flues above 6 inches in diameter, up to and including 16 inches, may be allowed a working pressure of 60 pounds per square inch, if their length does not exceed 18 feet and their thickness is as given in the table. When flues above 6 inches and not over 16 inches are made in sections not over 5 feet in length and securely riveted together, a working pressure of 120 pounds per square inch may be allowed.

Boiler tubes made of charcoal iron and lap-welded may be obtained in sizes up to and including 4 inches made one gauge thicker than those given in the table. These tubes are made especially for locomotive work and may be allowed a pressure not over 300 pounds per square inch.

48. Measurement of Heating Surface.—The heating surfaces of cast-iron sectional boilers having vertical slab sections, such as are commonly employed in heating buildings of moderate size, are not measured according to any universally recognized standard. In some cases the amount of heating surface is determined by actual measurement. Another method is to consider the heating surface of each vertical section as being equivalent to that of two flat surfaces of the same width as the section across the flues, i. e., from outside edge of flue on one side of boiler to outside edge of flue on the other side, and of the same height as the section from the grate line to the extreme top, adding the average depth or thickness of a single section to the width. Thus, if the width of the section across the flues is 42 inches, its thickness or depth 8 inches, and its height above the grate line 60 inches, $(42 + 8) \times 50 = 250$ square inches is taken as the area of one side, and $\frac{2 \times 250}{144}$

= 3.5 square feet as the heating surface of each section, except the front and rear sections, each of which is calculated as having one-half this amount of surface. In other words, the combined heating surface of the front and rear sections is considered as being equal to that of one intermediate section. In applying this method to boilers fitted with steam drums, the capacity of which boilers is slightly greater than that of similar boilers without steam drums, it is customary to add about 10 per cent. to the actual height of the section to compensate for the difference in capacity.

EXAMPLE.—A sectional domestic heating boiler has 12 sections, each 48 inches wide across the flues, 52 inches in height above the grate line, and 8 inches in depth. What would be the approximate heating surface?

SOLUTION.—The front and rear sections together being considered as equivalent to a single intermediate section, there are 11 sections whose heating surface is to be determined. Hence, the total amount of heating surface in the boiler is

$$\frac{(48 + 8) \times 52 \times 2 \times 11}{144} = 445 \text{ sq. ft., nearly. Ans.}$$

When the amount of heating surface is determined in the manner last indicated, it is customary with manufacturers to rate the boiler on the basis that 1 square foot of heating surface is approximately equivalent to 10 square feet of direct radiation, so that a boiler having the dimensions given in the example would be rated to supply $445 \times 10 = 4{,}450$ square feet of direct radiation.

49. The heating surface of return-tubular boilers may be calculated quite closely by the following approximate rule:

Rule.—*Multiply two-thirds of the circumference of the shell in inches by its length in inches; multiply the number of tubes by the length of the tube in inches and by its circumference; add to the sum of these products two-thirds of the area in square inches of the two heads or tube sheets; from this sum subtract twice the area of all the tubes and divide the remainder by 144; the result is the required heating surface in square feet.*

EXAMPLE.—A horizontal return-tubular boiler has the following dimensions: Diameter, 60 inches; length of tubes, 12 feet; internal diameter of tubes, 3 inches; number of tubes, 82. What is the heating surface?

Solution.—Circumference of shell, $60 \times 3.1416 = 188.496$ = say 188.5 in.; length of shell, $12 \times 12 = 144$ in.; heating surface of shell, $188.5 \times 144 \times \frac{2}{3} = 18{,}096$ sq. in.; circumference of tube, $3 \times 3.1416 = 9.425$, nearly; heating surface of tubes, $82 \times 144 \times 9.425 = 111{,}290.4$ sq. in.; area of one head, $60^2 \times .7854 = 2{,}827.44$ sq. in.; two-thirds area of both heads, $\frac{2}{3} \times 2 \times 2{,}827.44 = 3{,}769.92$ sq. in.; area through tubes, $3^2 \times .7854 \times 82 = 579.63$ sq. in.

Applying the rule,

$$\text{heating surface} = \frac{18{,}096 + 111{,}290.4 + 3{,}769.92 - 2 \times 579.63}{144}$$
$$= 916.64 \text{ sq. ft. Ans.}$$

50. For boilers for which no special method is here given, the heating surface must be calculated by the ordinary rules of mensuration from the actual dimensions as taken from a working drawing or found by actual measurement.

51. Ratio of Heating Surface to Grate Area.—In order to obtain the best results from a boiler, the temperature of the products of combustion should pass into the chimney at as low a temperature as possible. To give these hot gases a chance to give up their heat to the water, a large amount of heating surface is necessary. The higher the rate of combustion, the greater should be the heating surface.

In practice, the ratio between the heating surface and grate area varies with the type of boiler and the rate of combustion. The following are average values:

TABLE IV

PROPORTIONS OF HEATING SURFACE TO GRATE SURFACE

Type	Ratio = $\frac{\text{Heating Surface}}{\text{Grate Area}}$
Plain cylindrical	12 to 15
Flue	20 to 25
Return-tubular	25 to 35
Vertical	25 to 30
Water-tube	35 to 40
Locomotive	50 to 100
Cast-iron sectional	10 to 30

From a large number of tests, Mr. G. H. Barrus concludes that with bituminous coal a return-tubular boiler gives the best results when the ratio is between 45 to 50, provided the rate of combustion is not more than 12 pounds per square foot of grate surface per hour. Under the same circumstances the ratio should be 36 when the boiler uses anthracite coal.

52. Ratio of Heating Surface to Radiation.—The amount of heat absorbed and transmitted by the heating surface is determined by the rapidity of the circulation of the heated gases and of the water and the difference in temperature between them. In the ordinary forms of house-heating boilers from 1,800 to 2,400 British thermal units are absorbed per square foot of heating surface per hour, and since 1 square foot of direct steam radiating surface requires from 250 to 330 British thermal units, say an approximate average of 300 British thermal units per hour, it is evident that 1 square foot of boiler heating surface would generate enough steam to supply from 6 to 10 square feet of radiating surface. In other words, a vertical sectional boiler having 200 square feet of heating surface would supply sufficient steam for from 1,200 to 2,000 square feet of direct radiation, including all losses due to condensation in the transmission of the steam through the supply piping.

GRATE SURFACE

53. Required Area of Grate.—The area of grate surface required in any given case depends on the type of boiler employed, the amount of water to be evaporated, the nature and amount of coal to be burned, and the rate of combustion which varies from 3 to 20 or more pounds of coal per square foot of grate per hour. The general rule for finding the grate surface is as follows:

Rule.—*To find the grate surface, in square feet, divide the weight of steam in pounds required per hour by the product obtained by multiplying the number of pounds of coal burned per square*

foot of grate per hour by the number of pounds of water evaporated per pound of coal.

Or, $$G = \frac{W}{CE}$$

where G = grate surface, in square feet;
W = weight of steam, in pounds per hour;
C = pounds of coal per hour per square foot of grate surface;
E = evaporation, in pounds per pound of coal.

In this rule no account has been taken of the difference in the number of heat units required to evaporate wafer from different feedwater temperatures into steam at different pressures. Hence, the rule is only approximate, but close enough for practical work.

The average evaporation per pound of coal for different kinds of boilers is given in the following table:

TABLE V

AVERAGE EVAPORATION PER POUND OF COAL

Type of Boiler	Coal Burned per Hour per Square Foot of Grate Area			
	6 to 10	10 to 14	14 to 18	18 to 20
	Water Evaporated per Pound of Coal Pounds			
Cylindrical	7.00	6.75	6.50	6.00
Two-flue	7.25	7.00	6.75	6.25
Return-tubular	9.00	8.50	8.25	8.00
Firebox	9.00	8.50	8.25	8.00
Vertical tubular	8.00	7.75	7.50	7.00
Water-tube	10.50	10.00	9.00	8.00
Cast-iron sectional	8.60			

The table gives the evaporation per pound of coal that may be expected under average conditions, but the actual evaporation obtained may be less or more than that given in

the table, which is intended merely as an approximate guide when there is no available data showing the evaporation of the kind of boiler selected under conditions similar to those that will obtain when the proposed plant is operated.

EXAMPLE.—A cylindrical boiler is to generate 600 pounds of steam per hour, burning 10 pounds of coal per square foot of grate surface per hour. What grate surface will be required?

SOLUTION.—By Table V, an evaporation of 6.75 pounds of water per pound of coal may be expected. Then, applying the rule given,

$$G = \frac{600}{10 \times 6.75} = 8.8 \text{ sq. ft., nearly. Ans.}$$

54. Ratio of Grate Surface to Radiation.—The requisite area of grate necessary to supply a given amount of direct steam radiation may be found approximately by dividing the total amount of radiating surface by a factor varying between 100 and 160, selecting a factor in accordance with the character and probable management of the heating boiler. For ordinary work, where the boiler is given attention by unskilled labor, a factor of 100 may be used to advantage; when a skilled fireman attends the boiler, a factor of 160 may be selected. For example, a heating boiler rated to supply 1,600 square feet of direct radiation, including ordinary losses, should have a grate area of $\frac{1600}{100} = 16$ square feet if operated under ordinary conditions, or $\frac{1600}{160} = 10$ square feet if the boiler is to be carefully handled.

55. The ratios of grate surface to radiating surface, grate surface to heating surface, and radiating surface to heating surface of different types of steam-heating boilers in the market, and given in Table VI, were assembled by a writer from information given in catalogs, etc., and first published in Heating and Ventilation, now The Engineering Review. This table will be useful as showing the average practice of American manufacturers of steam-heating boilers.

EXAMPLES FOR PRACTICE

1. A sectional domestic heating boiler has 8 sections 24 inches wide across the flues, 30 inches high above the grate, and 6 inches deep. Approximately, what is the heating surface? Ans. $87\frac{1}{2}$ sq. ft.

TABLE VI

PROPORTIONS OF STEAM-HEATING BOILERS

Kinds of Boilers	Square Feet of Radiation														
	250	500	750	1,500	2,000	250	500	750	1,500	2,000	250	500	750	1,500	2,000
	Square Feet of Radiating Surface per Square Foot of Grate Surface					Square Feet of Heating Surface per Square Foot of Grate Surface					Square Feet of Radiating Surface per Square Foot of Heating Surface				
Tubular, vertical, magazine	134	167	167	180	228	23	30.0	23.0	24.0	30	5.8	5.6	7.3	7.4	7.7
Tubular, vertical, surface	180	190	200	190	220	30	32.0	33.0	34.0	36	6.0	6.0	6.0	6.0	6.0
Tubular, vertical, steel	170	147	138			30	24.0	25.0				3.5	4.7		
Vertical shell, drop and fire-tube	140	170	170	180		26	32.0	30.0	30.0		5.0	5.3	5.5	5.7	
Pipe boiler	180	180	180	180	180	20	23.0	25.0	27.0	30	6.2	6.5	6.0	6.0	6.0
Pipe-coil boiler	75	75	75	75	75	25	25.0	25.0			3.0	3.0	3.0		
Drop-tube, wrought-iron	185	195	205			42	36.0	33.0	32.7		4.4	5.4	6.0	6.5	
Drop-tube, cast-iron, magazine	198	172	204			36	28.7	35.7			5.5	6.0	5.7		
Drop-tube, cast-iron, surface	240	186	224			43	32.0	40.0			5.4	5.8	5.7		
Drop-tube, magazine		180	170	170	180		36.0	27.0	23.0	22		5.0	5.0	6.0	7.0
Drop-tube, wrought-iron	165	165				35	37.0				4.5	4.5			
Drop-tube, wrought-iron	150	150				22	25.0				6.3	6.0			
Coil and drop-tube		240	200	210	230		44.0	40.0	35.0	27		5.0	6.2	7.3	8.3
Horizontal sectional	160	200	216	216		32	35.0	36.0	36.0		4.0	5.7	6.0	6.0	
Horizontal sectional		180	200	300			36.0	26.0	36.0		4.0	5.0	6.0	6.5	
Horizontal sectional	170	147	138			30	24.0	25.0			5.0	5.0	4.7		
Vertical sectional	130	112	130	130		16	24.0	24.0	24.0		5.7	5.0	5.7	6.0	
Vertical sectional		135	150	155	155	28	30.0	25.0	25.0	24		5.3	6.0	5.7	6.0
Vertical, sectional, tubular	130	145	138	163	167		23.0	20.0	25.0	30	6.0	6.5	7.0	5.7	6.3
Vertical, sectional, tubular		192	200	230	250		32.0	33.0	37.0	40		6.0	6.0	6.0	6.0

2. How many square feet of direct radiation would the boiler of example 1 be usually rated for? Ans. 875 sq. ft.

3. Calculate the heating surface of a horizontal return-tubular boiler 54 inches in diameter and containing 74 tubes 10 feet long and 2 inches inside diameter. Ans. 500 sq. ft., nearly

4. What grate surface should be given to a vertical tubular boiler burning 8 pounds of coal per hour per square foot of grate surface, the boiler being required to generate 300 pounds of steam per hour? Ans. 4.69 sq. ft.

BOILER RATINGS

56. Horsepower of Power Boilers.—Strictly speaking, there is no such thing as the horsepower of a boiler. This phrase was originally intended to mean that a boiler having a certain stated horsepower would furnish all the steam that was required to develop that amount of power in a given engine. This meant that if a certain boiler furnished steam for a 30-horsepower engine, it would be called a 30-horsepower boiler; and if the same boiler furnished steam for a 50-horsepower engine, it would be called a 50-horsepower boiler. It is thus seen that this rating had no particular significance.

Boilers are often rated by their ability to evaporate water from and at a temperature of 212° F. into dry steam, 34.5 pounds per hour being reckoned as 1 horsepower. This method, however, is merely an indirect way of arriving at the number of British thermal units transmitted through the boiler. The rating of boilers by the number of British thermal units actually transmitted per hour is one that permits of a direct comparison of the relative heating capacities of all kinds of steam and hot-water boilers.

In order to have a definite standard of comparison, the American Society of Mechanical Engineers has accepted the report of a committee recommending that 33,330 British thermal units per hour transmitted from the fuel and absorbed by the water shall constitute a boiler horsepower. The acceptance of this report practically constitutes this amount of heat absorption as a standard boiler horsepower. The horsepower of a boiler, thus expressed, is the measure

of its performance under certain given conditions, and does not indicate its capabilities when employed under other conditions. Thus, a boiler employed in heating water in an open system, with a slow fire, would develop a much smaller horsepower than it would if employed in making high-pressure steam, with forced blast and intense fire.

The standard boiler horsepower is given by the following rule:

Rule.—*Subtract the temperature of the feedwater in degrees Fahrenheit from the total heat of 1 pound of steam above 32° at the pressure of the actual evaporation. Add 32 to the remainder and multiply this sum by the weight of water evaporated per hour into dry steam. Divide the product by 33,330.*

Or,
$$P = \frac{[(H - t) + 32]W}{33{,}330}$$

where P = standard boiler horsepower;
H = total heat of 1 pound of steam at the observed pressure;
t = temperature of feedwater;
W = weight of water evaporated per hour.

EXAMPLE.—A boiler receives the feedwater at 62° and evaporates it into steam at 85 pounds gauge pressure, at which the total heat required to evaporate a pound of water from 32° is 1,181.8 British thermal units. If 2,300 pounds of water is evaporated into dry steam per hour, what is the standard horsepower of the boiler?

SOLUTION.—Applying the rule just given,

$$P = \frac{(1{,}181.8 \div 62 + 32) \times 2{,}300}{33{,}330} = 79.49. \text{ Ans.}$$

57. The amount of steam used by engines per horsepower per hour varies within such wide limits that a horsepower rating based on heat absorption, that is, evaporation, is in itself no indication that a boiler of a given standard rating is the correct size for an engine of an equal power. Furthermore, the same boiler may generate widely differing quantities of steam under different conditions, the amount of steam generated depending primarily on the combustion

rate and kind of fuel. Considering this fact, it is seen that the standard horsepower rating is a variable quantity of small value as a guide in the selection of a boiler.

58. It is the common practice of boilermakers to rate the horsepower of their boilers as a certain fraction of the heating surface expressed in square feet, each boilermaker using his own fraction for different types of boilers. These widely differing ratios between heating surface and horsepower average about as given in the following table:

TABLE VII

PROPORTIONS OF HEATING SURFACE TO HORSEPOWER

Type of Boiler	$\text{Ratio} = \dfrac{\text{Square Feet of Heating Surface}}{\text{Rated Horsepower}}$
Plain cylindrical . . .	6 to 10
Flue	8 to 12
Return-tubular . . .	14 to 18
Vertical	15 to 20
Water-tube	10 to 12
Cast-iron sectional . .	10 to 18

For example, a boilermaker rates his tubular boilers as having 16 square feet of heating surface to the horsepower. Then, a 35-horsepower boiler would have $35 \times 16 = 560$ square feet of heating surface. On the other hand, a similar boiler having 880 square feet of heating surface would be rated at $\frac{880}{16} = 55$ horsepower.

Since the heating surface is only one of the factors entering into the quantity of steam generated per hour, it follows that a horsepower rating based on heating surface alone is of small value as an aid in the selection of a boiler. About all that can be expected when buying a boiler according to this kind of rating is to receive an amount of heating surface depending on what ratio the maker of the boiler has adopted. The boiler, if thus bought, may or may not be suitable for the service it is to perform.

59. The factors that determine the steam-making capacity of a boiler are the amount of coal burned and the water evaporated into dry steam per pound of coal. The amount of coal burned depends primarily on the extent of the grate surface, the kind of coal, and the intensity of the draft, and will vary under natural draft from 4 to 20 pounds per square foot of grate surface per hour, averaging about 8 pounds. One pound of good coal will, on an average, evaporate about 8 pounds of water from a feedwater temperature of 100° into steam at 70 pounds gauge pressure, so that on an average $8 \times 8 = 64$ pounds of water are evaporated per hour per square foot of grate surface. On an average the heating surface of multitubular fire-tube boilers is made 32 times the grate surface, and hence on an average $\frac{64}{32} = 2$ pounds of water are evaporated per square foot of heating surface per hour. Multitubular boilers, on an average, have 15 square feet of heating surface per rated horsepower, evaporating under the average conditions stated $2 \times 15 = 30$ pounds of water per hour. As this is the steam consumption per horsepower of the average engine, it will be seen that *for average conditions* a power boiler may safely be selected in accordance with the horsepower rating based on heating surface.

60. The amount of heating surface a power boiler should have for conditions not approximating the average, may be found by the following rule:

Rule.—*Multiply the weight of steam required per hour, in pounds, by the number of square feet of heating surface per square foot of grate surface corresponding to the type of boiler, as given in Table IV. Divide the product by the product obtained by multiplying the combustion rate in pounds per square foot of grate surface per hour by the number of pounds of water evaporated per pound of coal, as given by Table V. The quotient will be the heating surface.*

Or, $$S = \frac{WR}{CE}$$

where S = heating surface, in square feet;
W = weight of steam, in pounds per hour;
R = square feet of heating surface per square foot of grate surface;
C = combustion rate in pounds per hour per square foot of grate surface;
E = evaporation per pound of coal, in pounds.

The probable combustion rate of coal under natural draft can be estimated from the size of the chimney by the aid of Mr. William Kent's rule for horsepower of chimneys, given in Art. **40.** If data obtained in actual practice are available, giving the combustion rate of a similar coal with a chimney similar to that of the proposed installation, these data should be given preference. To estimate the probable coal consumption, multiply the horsepower found by rule II, Art. **40,** by .6 and divide the product by the actual chimney area in square feet.

In taking a value from Table IV, it is well, in case it is doubtful what proportion of heating surface to grate surface has been adopted by the maker of the boiler it is proposed to install, to use the larger value given, as this practice will cause an error on the safe side, that is, give an ample heating surface.

EXAMPLE.—What heating surface should be given to a return-tubular boiler that is to furnish 6,000 pounds of steam per hour? It is proposed to use a chimney 100 feet high and having an actual area of 7 square feet.

SOLUTION.—From Table IV, the number of square feet of heating surface per square foot of grate surface may be taken as 35. By rule I, Art. **40,** the effective area of the chimney is $7 - .6\sqrt{7} = 5.4$ sq. ft. The horsepower of the chimney, by rule II, Art. **40,** is $3.33 \times 5.4 \times \sqrt{100} = 180$. Then, the combustion rate is $\frac{180 \times .6}{7} = 15.4$ pounds per square foot of grate surface per hour. From Table V, the evaporation per pound of coal may be taken as 8.25 pounds of water.

Applying the rule given at the beginning of this article,

$$S = \frac{6,000 \times 35}{15.4 \times 8.25} = 1,654 \text{ sq. ft. Ans.}$$

61. Rating of Domestic Heating Boilers.—The power, that is, the heating capacity, of a house-heating boiler

is determined by the character, form, and amount of heating or fire surface, the relative amount of grate surface, and the water- and steam-holding capacity of the boiler. The efficiency of such a boiler depends on the proper relations of these factors, and also on the amount and kind of fuel burned in a given time. Although commonly employed as a unit for expressing the relative capacity of power boilers, the horsepower, especially when applied to domestic heating boilers, does not represent a satisfactory unit of rating or standard by which the power or steam-generating capacity of such heaters may be compared. Domestic heating apparatus may be satisfactorily rated by using 1 square foot of direct radiating surface as a unit for determining their relative power, which may be expressed in horsepower, if desired, on the basis that 1 boiler horsepower equals 33,330 British thermal units per hour, absorbed and transmitted from the fuel to the water. With temperature differences such as commonly exist between steam-heated radiators and the air surrounding them, say 150°, 1 square foot of direct radiating surface gives off from 250 to 330 British thermal units per hour, and since the evaporation of 1 pound of water from and at 212° F. into steam at atmospheric pressure requires 966 British thermal units, it is apparent that each square foot of radiation requires practically from $\frac{250}{966}$ to $\frac{330}{966} = \frac{1}{4}$ to $\frac{1}{3}$ pound of steam per hour. On this basis it can be assumed that 1 boiler horsepower is capable of supplying from 100 to 130 square feet of direct radiating surface, including all ordinary losses. In other words, an approximate horsepower rating may be substituted for the radiating surface rating by multiplying the number of horsepower by 100, the direct radiation equivalent of a horsepower; or, by dividing a given amount of radiating surface by 100, the required horsepower of the boiler necessary to supply it with steam may be determined.

62. Low-pressure steam-heating boilers may also be rated according to the amount of their heating surface, allowing from 10 to 18 square feet of heating surface as equivalent to 1 boiler horsepower. On the basis of 10 square feet

of heating surface per horsepower (34.5 pounds of water evaporated) an evaporation of $\frac{34.5}{10} = 3.45$ pounds of water per square foot of heating surface would be required, while ratings of 15 and 18 square feet of heating surface per horsepower would respectively necessitate an evaporation of $\frac{34.5}{15} = 2.3$ pounds and $\frac{34.5}{18} = 1.92$ pounds per square foot of heating surface. The evaporative efficiency of domestic heating boilers is low, because of the imperfect combustion due to careless firing and poor draft, and also on account of their generally bad management, being in many cases entrusted to servants who understand little, and care less, about the proper way to handle them. Under favorable conditions, however, where the draft is satisfactory and the management good, such heating boilers give results closely approximating those obtained with boilers used for power purposes. The element of size alone does not determine the actual capacity of a heating boiler, which may, under favorable conditions, be greater than its rated capacity, depending on the care and skill with which it is managed and fired.

63. Boiler ratings determined by laboratory tests, which are usually made under the most favorable conditions, and with expert firing, are of comparatively little value as establishing standards of capacity on which it is wise to base the selection of a boiler required to do a given amount of work in house heating. As some catalog ratings would seem to indicate an evaporative efficiency for heating boilers in excess of that claimed for the best types of power boilers, it is a good plan in laying out a steam plant to calculate the probable capacity of the boiler selected, according to the grate area and amount of heating surface, as well as radiation to be supplied. The manner of doing this can be best shown by an example.

A boiler having a grate 24 inches by 50 inches is rated by the maker to supply 2,100 square feet of direct radiating surface, and it is desirable to know whether this rating

accords with the generally accepted rules by which the capacity of the boiler is approximately determined.

The coal consumption per square foot of grate surface varies in heating boilers between 4 and 8 pounds per hour, averaging about 6 pounds. The amount of heat usefully absorbed by the boiler per pound of fuel may be assumed to be 8,000 British thermal units per hour, and the heat emitted per square foot of radiation may be taken as 300 British thermal units per hour. The grate area $= \frac{24 \times 50}{144} = 8.33$ square feet. Then, the number of British thermal units absorbed by the boiler per hour may be estimated to be $8.33 \times 6 \times 8{,}000 = 399{,}840$ British thermal units. This heat absorption per hour will supply $\frac{399840}{300} = 1{,}333$ square feet, nearly, of direct radiation. This conservative estimate is seen to be $\frac{2{,}100 - 1{,}333}{2{,}100} = .365 = 36.5$ per cent. less than the manufacturer's rating.

The apparent discrepancy between the estimated capacity and the manufacturer's rating is due to the assumptions of the manufacturer that the boiler will work under the best conditions, burning about 8 pounds of coal per square foot of grate surface, and that the heat emission is 250 British thermal units per square foot of radiation per hour. Under these assumptions, which it is unsafe to make for the conditions existing ordinarily in domestic heating, the heat transmitted to the water per hour is $8.33 \times 8 \times 8{,}000 = 533{,}120$ British thermal units, and the amount of radiation that can be supplied is $\frac{533120}{250} = 2{,}132$ square feet, or, in round numbers, 2,100 square feet.

STRENGTH OF CYLINDRICAL BOILERS

64. It is the aim of boiler manufacturers to make all parts of their boilers of equal strength, and this practice is so thoroughly carried out in good work that in nearly all cases it is perfectly safe to calculate the steam pressure that can safely be carried on the boiler by considering the stress some part can safely bear. The part selected in cylindrical

boilers is usually the boiler shell, chiefly on account of the simplicity of the calculations involved.

All authorities are agreed that a steam boiler should not be worked at a pressure near the bursting pressure, but there is considerable disagreement as to the ratio the safe working pressure should bear to the bursting pressure. This difference of opinion accounts for the variation in the results obtained by the application of different rules. The most general practice is to make the working pressure one-fifth of the bursting pressure, or in other words, to use a factor of safety of 5. On this basis we have the following rule:

Rule.—*To find the safe working pressure of a cylindrical boiler, in pounds per square inch, multiply the thickness of the material in inches by its ultimate tensile strength in pounds and by the efficiency of the longitudinal joint. Divide the product by 5 times the internal radius in inches.*

Or,
$$P_s = \frac{t\,T\,E}{5\,r}$$

where P_s = safe working pressure, in pounds per square inch;
t = thickness of shell, in inches;
T = ultimate tensile strength, in pounds per square inch;
E = efficiency of longitudinal joint;
r = radius of boiler.

The efficiency of a riveted joint may be defined as the ratio of the strength of the joint to that of the solid plate, the strength of the latter being considered as 1. Thus, if the efficiency of a joint is .56, it means that the strength of the joint bears the same proportion to the strength of the solid plate that .56 does to 1. The average efficiencies of well-designed riveted joints as met with in steam boilers are about as follows: Single-riveted lap joint and single-riveted butt joint with single cover-plate, .56; double-riveted lap joint and double-riveted butt joint with single cover-plate, .7; triple-riveted lap joint, .75; double-riveted butt joint with two cover-plates, .76; triple-riveted butt joint with two cover-plates, .85.

Example.—A boiler 48 inches in diameter is constructed of steel plate having an ultimate tensile strength of 55,000 pounds per square inch, and $\frac{1}{4}$ inch thick. The longitudinal seam being a double-riveted lap joint, what working pressure would be allowed?

Solution.—The average efficiency of a double-riveted lap joint is .7. Then, applying the rule just given,

$$P_s = \frac{\frac{1}{4} \times 55{,}000 \times .7}{5 \times \frac{48}{2}} = 80.2 \text{ lb. per sq. in., nearly. Ans.}$$

EXAMPLES FOR PRACTICE

1. A boiler is worked at 90 pounds absolute pressure, receiving the feedwater at an average temperature of 140° F., and evaporates 400 pounds of water per hour into dry steam. The total heat of 1 pound of steam at 90 pounds absolute pressure being 1,179.6 British thermal units, what is the standard horsepower of the boiler?

Ans. 12.86 H. P.

2. A boiler 44 inches in diameter is constructed of plate $\frac{3}{8}$ inch thick and having a tensile strength of 60,000 pounds. The joint being a double-riveted butt joint with two cover-plates, what working pressure may be allowed on the boiler? Ans. 155.5 lb., nearly

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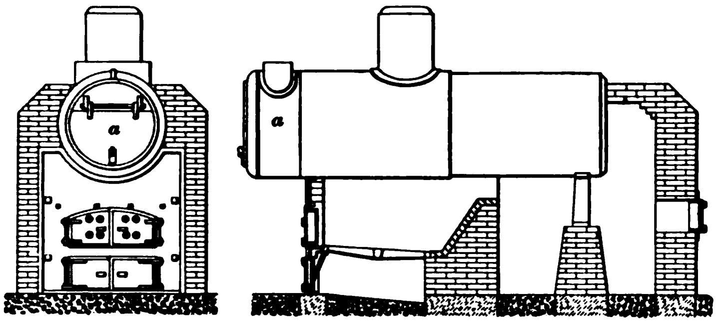
BOILER SETTINGS

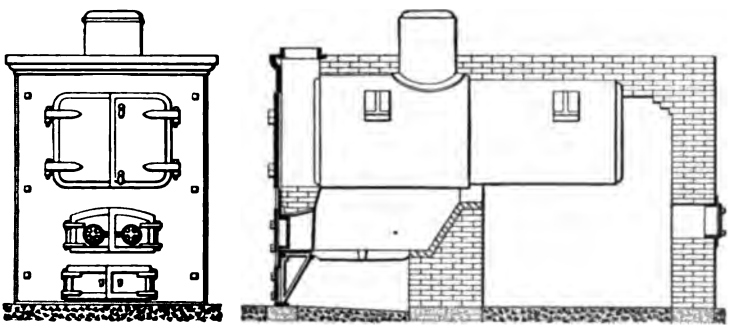
65. Setting of Sectional Boilers.—The majority of the boilers used for heating buildings of moderate size have what is termed a *portable setting*, i. e., they are mounted without any brickwork whatever on cast-iron bases that, like the boilers, may be extended at will to accommodate any increase of capacity of the boiler made by adding other sections when there is a demand for more steam than the original size of boiler could supply. Vertical cast-iron boilers having slab sections require no outer casing, although they are frequently set in brickwork in order to prevent loss of heat, or to utilize the extreme outer surfaces of the sections as heating surface. The general custom, however, is to cover the exterior surface of the boiler with some non-conducting material, such as magnesia and asbestos, which is practically as efficient as the brick setting in preventing loss of heat. Other types of domestic heating boilers, especially those of circular form, are often fitted with a thin outer casing of black or galvanized iron, lined with

some non-conducting material, and providing a dead air space between the casing and the outer surface of the boiler sections.

66. Boiler Fronts.—The two styles of boiler setting in general use for tubular and flue boilers of the externally fired type are known, according to the construction of the



(a)



(b)
FIG. 9

boiler front, as the *half-arch front* setting and the *full-arch*, or *full-flush*, *front* setting. In the half-arch front setting, as shown in Fig. 9 (*a*), the smokebox *a* is made of metal and projects beyond the boiler front; it either forms part of the boiler itself or is separate and fastened to the front boiler head. In the full-flush front setting, the sides of the

smokebox are formed by the brick setting and the front by the boiler front, as shown in Fig. 9 (*b*).

The half-arch front setting has the advantage that it will occupy slightly less floor space and hence will take a smaller number of common bricks and firebricks than the full-flush front setting. In general, it will be from 15 to 18 inches shorter; the width of the setting will be the same in both styles. An objection urged against the half-arch front setting is that the projecting smokebox interferes, to some extent, with the work of the fireman.

67. Design of Boiler Settings.—In a boiler setting, three things are to be attained: (1) A firm support for the boiler shell; (2) properly arranged space for furnace and ash-pit; (3) a protective covering for the boiler that will, as far as possible, prevent loss of heat by radiation.

Externally fired boilers may be supported by cast-iron lugs riveted to the shell and resting on the side walls, or they may be suspended from overhead girders by means of hooks or rings. The former method is usually adopted for the comparatively short return-tubular boiler, while the latter is used for the long plain cylindrical and flue boilers. When very long cylindrical boilers are suspended at two points only, the excessive weight between the supports throws a heavy stress on the lower plates in the middle of the boiler; when a center support is added, the condition of things is still worse, because the lower part of the shell expands more than the upper, which causes the shell to sag in the middle, thus throwing all the weight on the center support. Numerous cases have occurred where the center support has given way under the stress and the shell has been ruptured by the shock. It is therefore important in supporting these long shells to arrange the supports so that each will bear its proper proportion of the load and at the same time allow the boiler to expand freely under all conditions of temperature.

68. The setting of a 60-inch return-tubular boiler with a half-arch front, as designed by the Hartford Boiler Insurance

ımpany, is shown in Fig. 10. The foundation is heavy ›nework laid to a depth of 3 or 4 feet below the surface. ı top of this is laid the brickwork. The side and rear ılls are double, with a 2-inch dead air space between the ıer and outer parts. The inside walls *I*, *I*, next to the rnace, are faced with firebrick, as is also the bridge and all ırtions in direct contact with the flames.

The boiler is supported by cast-iron lugs *L*, *L* riveted to the ell. These lugs rest on iron plates *M*, *M* placed on top the side walls. The front lugs rest directly on the plates, ıt the back lugs rest on rollers *O* of 1-inch round iron. he boiler is thus free to expand and contract. The rear all is 24 inches from the rear head of the boiler, so as to low the gases an opportunity to enter the tubes; above the ıbes, however, the wall is built in to meet the head and ›rms a roof for the chamber. The rear wall is provided ith a door *D* to remove the dirt and soot that collects back f the bridge and to provide a means of inspection.

The grate *G* is placed 24 inches below the shell; this is a ufficient distance for anthracite coal, but for bituminous oal it might better be 30 to 36 inches. The grate has a fall f 3 inches from front to rear, which facilitates the admis- ion of air to the rear of the grate and makes it somewhat asier to clear the spaces between the grate bars from elow. The back end of the boiler should be set about inch lower than the front end; this insures a thorough raining of the boiler when the blow-off is open.

The brickwork is closed in contact with the shell at the vel of the center of the upper row of tubes; this prevents e gases coming in contact with the plates above the water- ıe. Some boilermakers prefer to make a brickwork arch er the top of the boiler and to allow the gases to pass ck to the rear through the flue thus formed. The practice risky, as it may lead to the overheating of the upper tes. A safe rule is: "Never expose to fire or gases of nbustion any part of the shell not completely covered h water." This rule applies to the blow-off pipe as well, ich when not in use is empty; in order to prevent its

destruction by the gases of combustion and the heat, it should always be protected either by covering it with a larger pipe or by a cast-iron sleeve, or by bricking it in. The last method has the serious objection that it interferes with the examination of the pipe, which may corrode badly without its being discovered when bricked in.

The brickwork is strengthened by buckstaves *B*, *B* held together by tie-rods *T*. The buckstaves are best made of wrought-iron channel or angle iron. It will be noticed that in the present case the flue pipe *P* is rectangular, but the pipe *W* leading to the chimney is cylindrical. The purpose of the air spaces *S*, *S* is to prevent the conduction of heat to the outer walls and thus keep them cool. Its utility is somewhat doubtful, and many of the best boilermakers do not recommend it.

69. Plain cylindrical and flue boilers are set in about the same manner as the return tubular. Sometimes, however, when the shells are extremely long, two or even more bridges are placed beneath the shell to keep the heated gases in contact with it. Vertical and locomotive boilers and nearly all internally fired boilers are self-contained and require no setting. The vertical boiler is supported by the cast-iron base that forms the ash-pit. Firebox boilers, when stationary, are supported on cast-iron saddles and skids. It is not customary to provide vertical boilers and stationary firebox boilers with any protective covering.

70. In boiler settings the walls have not only the weight of the boiler and its attachments to sustain, but they must also resist the varying stresses caused by the alternate heating and cooling of the entire masonry. For this reason the foundations should be unusually heavy and the walls of ample thickness and properly lined with firebrick on the inside. Every sixth course of firebrick from the grate up must be a row of headers bonded into the masonry behind. By the term *headers* is meant that the bricks are set in with the ends as the exposed surface instead of the sides, as is the case with the other courses. This method

enables the bricks between each row of headers to be renewed when necessary without having to tear down the entire wall.

Firebrick linings suffer most where the bed of fire comes in contact with them; the frequent impact of the fire tools against the bricks also causes them to become loosened and broken. But, as the first row of headers is about 12 inches from the surface of the grate, it is safe from the contact of fire and the impact of tools. The headers also give strength to the linings. Firebrick must be set in fireclay, which should be mixed thin enough to just lay on the trowel, thus permitting the bricks to lay close to one another, the principal object of the fireclay being to fill up the existing inequalities between the bricks. The bricks should also be dipped in water before being laid, so as not to absorb that which is in the fireclay.

The joints between the bricks of the outer walls should be about $\frac{1}{8}$ inch thick, of good mortar, composed of 1 part lime and 5 parts of clean sand—sea sand is not suitable for this purpose because it is not sharp enough. When building the walls, allowance should be made for the expansion of the boiler, so that the walls will not suffer unduly.

The kind and extent of the bed for the foundation depend on the nature of the earth. If the earth is firm and tenacious, trenches may be dug where the walls will stand and a bed of concrete laid, on which good, flat stones laid in cement are placed. Joints must be broken at every course, laid so that a solid foundation will be the result. Should the earth be soft and yielding, the excavation should cover the entire area of the setting and should be filled to a good thickness with stones and concrete, on which the foundation may be started.

When boilers are to be set where quicksand is found, the excavation should be deep enough to admit of a good bed of gravel being rammed home to a thickness of not less than 18 inches. On this a bed of stone and concrete is to be placed, and finally the first course of large, flat stones is well laid in cement.

71. The setting of water-tube boilers differs from that of the horizontal tubular only in details and kind, rather than in principle. Different makes of water-tube boilers require different forms of setting, which are determined largely by the construction of the boiler, and hence no general rules can be given. Usually the manufacturers of water-tube boilers furnish drawings of the setting to the buyer; it is best, speaking generally, to follow their advice in setting such boilers.

SELECTION OF BOILERS

72. The selection of a type of boiler for a prospective plant or for one that already exists depends on several things that should be considered carefully before a decision is made. There is no doubt that in some cases it is difficult to make a selection of a type to meet all the requirements, but then the relative merits of the individual considerations should be weighed rather than the considerations themselves.

The principal considerations with which a person will have to deal when selecting a type of boiler for a given plant are the character of the feedwater; kind of service and safety; available space and labor; steam pressure to be carried; first cost; expense of operation and maintenance; and influence of locality.

73. In selecting a sectional boiler for heating purposes, care should be exercised in noting what provision has been made for expansion and contraction of the parts. In the sectional cast-iron forms of boilers the expansion of the forward section, owing to the higher temperature at that point, is greater than that of those sections that are farther removed from the fire. Expansion stresses are greater over the fire than directly through the flues, and sectional boilers that are connected with nipples into headers are liable to rupture where a large number of sections are connected together. Therefore, short and wide types of such boilers are preferable. In the steel-shell tubular type of boiler the expansion stresses come chiefly on the heads, which allow for the expansion. Shell and tubular boilers set in brickwork are

provided with expansion plates on the side walls, with rollers beneath supporting brackets riveted to the boiler shell.

74. Waters that abound in scale-forming matter warrant a decision in favor of the use of a plain cylindrical or the horizontal tubular boiler, because of the comparative ease with which they can be cleaned at a minimum cost. Water-tube boilers using such waters rapidly become filled with scale; the scale can be removed without injuring the boiler in most cases only by the application of expensive appliances, which, considering the type of boiler, consume considerable time in the operation.

75. Boilers that are to be installed in buildings in which there are a number of people should preferably be of the water-tube type, because of their comparative safety. Boilers that are in almost constant service, where time for repairing, cleaning, and overhauling is extremely limited, should be of the horizontal tubular type, because of their ability to stand such service for a longer period of time than most other types, and with the minimum amount of overhauling.

76. An important consideration that cannot be given too much thought is the kind of labor available. The water-tube boiler requires more care than the fire-tube boiler, which is so largely used in stationary work. A plant in which there is only one attendant should in general not be equipped with water-tube boilers, because the attendant will not have the requisite amount of time to properly care for them. On the other hand, plants that have an attendant just for the purpose of taking care of boilers could safely be equipped with water-tube boilers, so far as this consideration is concerned. Experience has shown that it requires a larger force of men to operate and maintain the water-tube boiler than it does for any other type. This statement is contrary to the claims of makers of water-tube boilers; however, it represents the opinion of many operating engineers.

77. The consideration of available space alone frequently leaves no choice in the matter. For shallow basements and

out-of-the-way corners, no boiler is as suitable as the horizontal return tubular. Of course, where space is plentiful, other considerations may cause a different type of boiler to be chosen.

78. Water-tube boilers are best adapted for high pressures, because they are stronger. Take, for instance, the tubes; in a water-tube boiler the pressure is internal, while in the fire-tube boiler or flue type, the pressure is external, tending to collapse the tube or flue. Now, since for equal thicknesses and diameters a cylindrical body will collapse under less pressure than that which will tear it asunder, it follows that the water-tube boiler, with tubes equal in size to those of a fire-tube boiler, will safely stand a higher working pressure.

79. When first cost is the principal consideration on which a selection is made, the plain cylindrical and horizontal tubular boilers are the most economical to purchase. But sometimes the practice of such initial economy proves to be the most expensive in the end, so that this consideration, apart from the others, should not be given too much weight. From this it must not be inferred that the most expensive boiler (first cost) is always the most economical. Other considerations and conditions bear largely on the question.

80. The principal item affecting the cost of operation of the different types of boilers is the evaporative efficiency of each. The boiler that has the highest efficiency will cost the least for operation, assuming other things to be equal. With regard to repairs, it may be said that in general the water-tube boiler is the most costly, if it is to be kept in first-class condition.

81. It would not be wise to install a boiler whose construction demands frequent overhauling and repairing to keep it in thorough condition in a place remote from where such work could be done by skilled hands and with the proper appliances. Such a location demands the simplest make of boiler and that which is the least liable to require extensive overhauling and repairs.

BOILER MANAGEMENT

CARE OF HEATING BOILERS

82. The efficiency of a domestic heating boiler largely lepends on the care with which it is managed. There should e enough water in the boiler to show a water-line at about he middle of the gauge glass. The fuel should be disributed over the grate surface in a moderately deep layer, nd the fire should be kept bright and free from clinkers. The ash-pit should be deep enough to admit of being easily leaned, and should be kept free from ashes to prevent burnng of the grates. The chimney and smoke pipe should be horoughly cleaned occasionally to insure good draft. The lamper regulator, if one is fitted, should be properly djusted, the draft lever, by shifting its weight outwards, eing more heavily weighted as the cold weather increases. The safety valve should occasionally be lifted from its seat o make sure it is in proper working order. Under no conlitions should the boiler be filled while hot. In case the vater should accidentally escape, through the breaking of a gauge glass or other cause, the fire should be dumped, allowng the boiler to cool sufficiently to avoid injury before it is gain filled with cold water. After the boiler has been idle luring the summer, the water in it should be drawn off, and should be well washed out before starting the fires, and all e fixtures should be carefully examined and put in order. Vhen winter is over, the boiler should be thoroughly cleaned nd so left that dry air may circulate over and around the xposed or exterior portions of the heating surface. The terior of the boiler should be thoroughly washed and filled mpletely with water in which a small amount of soda is aced to prevent rust. If the boiler is located in a damp ace, it is good practice to coat it with a good heavy oil, or int the exposed parts with asphaltum.

83. It is important that the water used in boilers should free from such impurities as would interfere with their

steam-generating power. In low-pressure steam-heating apparatus, where the water of condensation is returned by gravity to the boiler, there is usually little trouble with impurities in the water except in starting the apparatus for the first time, when the sediment and mineral salts held in solution are precipitated and should be blown off. The water of condensation from the radiators, purified by this precipitation, returns to the boiler to be reevaporated, small quantities of fresh water being fed to the boiler from time to time to make up for the loss occasioned by escaping watery vapor at air vents, etc. With careful handling and occasional blowing out, no bad effects will result from the use of impure water, provided it does not contain animal or vegetable oils or grease, which cause priming and corrosion. In boilers used for power, where little or none of the water of condensation is returned to the boiler, the water should be purified before being used.

CLEANING

84. In order to secure the greatest efficiency and economy in the operation of a boiler, it is necessary that all of the heating surfaces be kept clean, both on the inside and outside. The interior should be examined frequently, and no scale or mud should be permitted to remain. All heating surfaces should be kept clear of deposits of dust or soot, because they obstruct the transmission of heat. Dust or soot, burned on in a crust, should be removed with a scraper. Fire-tubes quickly fill up with dust, and must be cleaned with a brush or scraper at short intervals. Water tubes should be brushed and cleaned on the outside, to keep their surfaces in good condition for absorbing heat. Fire-tubes suffer more loss of efficiency by the accumulation of dirt than water tubes, as is clearly shown by Fig. 11. The

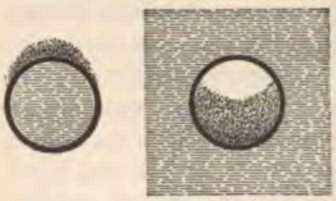


FIG. 11

deposit of dirt in the fire-tube not only reduces the amount of effective heating surface, but it also reduces the area of the flue, and thus obstructs the draft.

PRIMING AND FOAMING

85. In steam boilers employed for power purposes, and also in those employed for heating, it is sometimes found that the steam is very wet; in other words, it is mixed with water in the shape of minute bubbles, so that it exists in the condition of spray or mist. This spray does not readily settle while there is any perceptible current or motion in the steam, and it is likely to remain in suspension until the steam is lowered in pressure, or is partly condensed. A boiler giving very wet steam is said to be *priming*.

86. Priming, a condition seldom found in the ordinary type of domestic heating boiler, because of the low steam pressure carried, is caused by violent boiling, which projects the water into the steam space in a shower of drops. This is commonly due to the insufficiency of the disengaging surface, where the steam parts from the water, but it may also be caused, in cases where this surface is ample, by concentrating the rising currents of steam or steam-laden water too much at one point in the steam drum. In this case the trouble may be mitigated or overcome by checking the velocity of the currents and dispersing them over a larger area, by the judicious use of baffle plates.

It is necessary that the surface of the water in the steam drum should have sufficient area to permit the steam to rise from it, at a velocity not exceeding $2\frac{1}{2}$ feet per second. If this velocity is exceeded, the steam will carry more or less of the water with it in the condition of fine spray.

Boilers that have the fault of priming consume water very rapidly and apparently have great evaporative power. Their apparent evaporative efficiency, however, is very deceptive, because the steam produced is really a mixture of steam and hot water. The real evaporative power, measured by

the amount of heat carried by the steam, will usually be found to be quite small.

As the maximum theoretical evaporative power of 1 pound of coal is about 15 pounds of water, it follows that boilers which appear to consume 16 to 20 pounds of water per pound of fuel are very poorly designed.

87. Foaming occurs when the rising steam bubbles do not break on coming to the surface of the water, but retain the form of minute bubbles and unite into masses of foam. It is always due to impurities in the water, and can be cured only by using proper purifying apparatus, or by securing fresh, clean water.

Foaming should not be confused with priming. A boiler having no tendency to prime may foam badly if supplied with impure water; but, if it does prime, the foaming will be greatly increased.

Foaming is dangerous because the steam is loaded with such quantities of water that the power generating machinery is liable to be damaged, and the water is removed from the boiler so rapidly that, unless it be closely watched, the heating surfaces will become uncovered and burned.

INCRUSTATION AND SEDIMENT

88. Formation.—The deposit on the plates and tubes of a boiler caused by impurities in the water, which are left behind in the boiler is known as **incrustation** and also as **scale.** If the water used in a boiler were perfectly pure there would, of course, be no trouble from incrustation. Unfortunately, however, in passing through the soil, water dissolves certain mineral substances, the most important of which are carbonate of lime, which is the same thing as limestone or marble, and sulphate of lime, which is the same as plaster of Paris. Carbonate of lime will not dissolve in pure water, but will dissolve in water that contains carbon dioxide, CO_2. Sulphate of lime dissolves readily in cold water, but not in water heated to the boiling point at sea level, 212°.

The water in the boiler usually contains one or the other of these impurities, and often both. As the water is heated toward the boiling point, the carbonic acid in the water begins to be driven off, and the carbonate of lime remains dissolved no longer. Likewise, the sulphate will not remain dissolved after the water is sufficiently heated. Small particles of the carbonate and sulphate (marble and plaster of Paris) appear in the water in solid form. When the temperature of the water reaches 290°, that is, when the steam pressure reaches 45 pounds per square inch, gauge pressure, the water will hold none of either carbonate or sulphate in solution. It is all precipitated in solid form. These small solid particles remain for a time suspended in the water, but gradually settle on the plates, tubes, and other internal surfaces. A large part of the impurities will be carried by the circulation of the water to the most quiet part of the boiler, and there settle and form a scale. In a few weeks, if no means of prevention are used, the inner parts of the boiler will be covered with a crust from $\frac{1}{16}$ to $\frac{1}{2}$ inch in thickness.

A scale $\frac{1}{32}$ inch or less thick is thought by many to be an advantage, since it protects the plates from the corrosive actions of acids in the water. When, however, the scale becomes $\frac{1}{4}$ inch thick or more, heat is transmitted through the plates and tubes with difficulty, more fuel is required, and there is danger of overheating the plates.

Incrustation in many cases has led to danger and disaster by stopping up the feedpipe, the blow-off pipe, or the connections to the gauge glass. Again, the coat of scale may hide a dangerously corroded piece of plate or a defective rivet head, which would otherwise be discovered.

89. Carbonate of lime forms a soft, muddy scale, which when dry becomes fluffy and flour-like. This scale may be easily swept or washed out of the boiler by a hose, provided it is not baked hard and fast. A carbonate scale is much harder to deal with when grease is allowed to enter the boiler. The grease settles and mixes with the floury scale, making a spongy crust, which remains in contact with the plates,

being too heavy to be carried off by the natural circulation of the water. Many cases of overheated and burned plates are the direct result of allowing grease or animal oil to enter the boiler.

Sulphate of lime forms a scale that soon bakes to the plates, and can only be removed by mechanical means. In addition to the scales mentioned, a large amount of mud and earthy matter may be deposited by the use of dirty or muddy water.

90. Remedies for Incrustation.—The most efficient way of dealing with scale is to prevent its formation in the boiler. This may be done by passing the water through a purifier. Here the water comes in contact either with exhaust steam or with live steam from the boiler, and its temperature is raised until the carbonates and sulphates are precipitated. The water passes on into the boiler while the scale stays behind in the purifier, from which it may be removed without trouble. What little scale forms in the boiler may be removed by blowing off.

When the water contains a large amount of mud or earthy matter, it should be filtered through beds of pebbles or bones before being used.

The readiest method of removing impurities after they are deposited in the boiler is by the blow-out apparatus. A large part of the scale is naturally carried to the coolest part of the boiler (to the mud-drum, if there is one), and may be removed by partly blowing off the boiler while under steam pressure.

The fact that many impurities are held in suspension, and float as a scum on the water for some time before settling has led to the use of surface blow-out apparatus, of which the Hotchkiss mechanical cleaner is one form. It consists of a cast-iron spherical vessel situated on top of the boiler. This vessel is connected to each end of the boiler by a pipe. On one end of the pipe leading to the front end of the boiler (called the uptake pipe) is a large funnel, so placed as to be partly submerged in water. When the boiler is in operation, the natural circulation of the water causes it to rise in

the uptake pipe and flow into the spherical vessel, the funnel scooping in the impurities floating on the top. The water then flows out through the downtake pipe into the rear, or cooler, end of the boiler. The water in the vessel being comparatively quiet, the impurities are deposited at the bottom and may be blown out at intervals.

A frequent use of both surface and bottom blow-outs will keep a boiler comparatively free from incrustation. Incrustation is prevented to a large extent by a rapid water circulation. This is one of the chief merits claimed for the water-tube boilers; the sediment is swept through the tubes and shell and deposited in the lowest part of the boiler—the mud-drum.

91. Various chemical substances are introduced into the boiler to combine with the scale-forming material and change its character. The cheapest and most effective of these substances is carbonate of soda. When the scale consists of sulphate of lime, the combination of the soda and sulphate results in the formation of sulphate of soda, which is soluble, and carbonate of lime, which forms a soft scale that is easily blown off. Where the water contains carbonate of lime, sal ammoniac or caustic lime may be used to prevent a hard incrustation. Sometimes organic substances containing tannic acid, such as oak bark, hemlock, or sumac, are employed to loosen or prevent scale. They are liable to injure the plates by corrosion, and hence should not be used. The following is a list of troublesome scale-forming substances and their remedies:

Troublesome Substances	Trouble	Remedy or Palliative
Sediment, mud, clay, etc.	Incrustation	Filtration Blowing off
Readily soluble salts	Incrustation	Blowing off
Bicarbonates of lime, magnesia, iron	Incrustation	Heating feed Addition of caustic soda, lime, or magnesia

Troublesome Substances	Trouble	Remedy or Palliative
Sulphate of lime	Incrustation	Addition of carbonate of soda or barium chloride
Chloride and sulphate of magnesium	Corrosion	Addition of carbonate of soda, etc.
Carbonate of soda in large amounts	Priming	Addition of barium chloride
Acid (in mine water)	Corrosion	Alkali
Dissolved carbonic acid and oxygen	Corrosion	Heating feed Addition of caustic soda, slacked lime, etc.
Grease (from condensed water)	Corrosion	Slacked lime and filtering. Carbonate of soda Substitute mineral oil
Organic matter (sewage)	Priming	Precipitate with alum or chloride of iron and filter
Organic matter	Corrosion	Same as last

92. Zinc is largely used in marine boilers for the prevention of both incrustation and corrosion. The scale may acquire thickness and hardness, but can easily be removed from the plates. It is supposed that the zinc in connection with the iron of the plates keeps up a feeble galvanic action, and that the hydrogen liberated at the surface of the plate by this action prevents the incrustation from adhering to it. The zinc is distributed through the boiler in the form of slabs. About 1 square inch of zinc surface should be supplied for every 50 pounds of water. Kerosene oil has been found useful in preventing and removing scale. It is claimed by those who have used it that 1 quart per day per 100 horsepower is

sufficient to keep boilers free from scale, though using very hard and impure water. It is also effective in breaking up and loosening hard scale after it is formed. The most certain and effective remedy for incrustation after it has been once deposited is to remove it mechanically at certain intervals. The boiler should be entered and the scale chipped off or pulled off by hand.

CORROSION

93. Corrosion may be defined as the eating away or wasting of the plates due to the chemical action of water. It is probably the most destructive of the various forces that

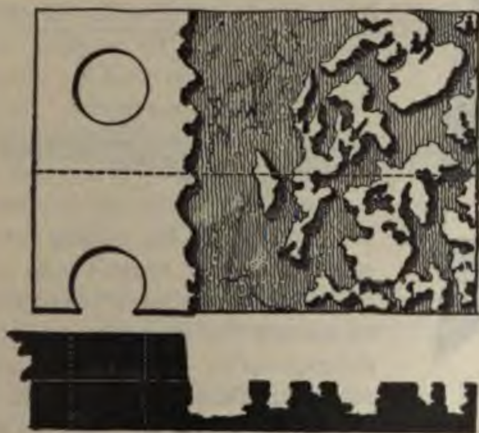


FIG. 12

tend to shorten the life of the boiler. Corrosion is of two forms—internal and external. Internal corrosion may present itself as: (1) uniform corrosion; (2) pitting or honeycombing; (3) grooving.

In cases of uniform corrosion, large areas of plate are attacked and eaten away. There is no sharp line of division between the corroded part and the sound part of the plate, and oftentimes the only way of detecting the corrosion is to drill a hole through the suspected plate and thus ascertain its thickness. Corrosion often violently attacks the staybolts and rivet heads.

Pitting and honeycombing are readily perceived. The plates are in spots indented with holes and cavities from $\frac{1}{32}$ to $\frac{1}{4}$ inch deep. The appearance of a pitted plate is shown in Fig. 12.

Grooving is generally caused by the buckling action of the plates when under pressure. Thus, the ordinary lap joint of a boiler distorts the shell slightly from a truly cylindrical form, and the steam pressure tends to bend the plates at the joint. This bending action is liable to start a small crack along the lap, that, being acted on by corrosive agents in the water, soon deepens into a groove, as shown in Fig. 13. The mark made along the seam by the sharp calking tool, when used by careless workmen, is almost certain to lead to grooving.

FIG. 13

To prevent corrosion, the feedwater should be as free as possible from corrosive impurities. When bad water must be used, the corrosive impurities should be neutralized by adding alkaline substances, such as caustic soda or soda ash.

External corrosion frequently attacks stationary boilers, particularly those set in brickwork. The causes of external corrosion are dampness, exposure to weather, leakage from joints, moisture arising from the waste pipes or blow-out, etc. When leakage occurs in a joint which is hidden by the brickwork setting, the plates may be corroded very seriously without being discovered.

External corrosion should be prevented by keeping the boiler shell free from moisture, and by repairing all leaks as soon as they appear. Joints and seams should be in position where they may be inspected for leaks.

LEAKAGE AND OVERHEATING

94. Leakage at the seams may be caused by delivering the cold feedwater on to the hot plates; another cause is the practice of emptying the boiler when hot and then filling it

with cold water. The leakage in both cases may be traced to the sudden contraction of the plates due to the sudden cooling. In any case, abrupt changes in the temperature of the shell should be avoided. The rush of cold air into the furnace of an externally fired boiler when the door is opened is a fruitful source of leakage and fracture. For this reason the shell should be constructed, if possible, so that none of the seams are in contact with the fire.

95. Overheating may be caused by low water or by incrustation. When the plate is covered by a heavy scale, the heat is not carried away by the water fast enough to

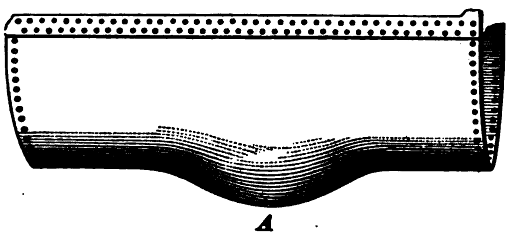


FIG. 14

prevent a rise of temperature, the plate becomes red hot and soft, and yields to the steam pressure, forming a pocket *A*, as shown in Fig. 14.

If the pocket is not discovered and repaired, it stretches until finally the material becomes too thin to withstand the steam pressure; the pocket bursts, and an explosion follows. Vegetable and animal oils, mixed from any cause with the feedwater, are particularly liable to cause the formation of pockets.

INSPECTION AND TESTING

96. The condition of a boiler as regards safety can be determined only by careful inspection. Insured boilers are periodically inspected by experienced inspectors in the employ of the insurance company. The inspector notes the condition of the plates, whether or not they are corroded or incrusted, inspects the interior in search of broken stays or rivets,

fractured joints, etc. The condition of the plates is generally determined by tapping them with a light hammer; any weakness will immediately reveal itself to the skilled inspector, who is able to judge the relative thickness and soundness of the plate by the sound of the blow and the rebound of the hammer. When the thickness is a matter of doubt, a small hole may be drilled through the plate, and afterwards plugged up.

The inspection of steam boilers should begin at the place where the plates are manufactured, and continue as long as the boiler is in use.

97. Boilers are often submitted to the hydrostatic test. The boiler is filled with water, a pump is applied and more water is forced in, until the pressure exceeds by 50 per cent. or more that which the boilers are expected to carry. If the boiler stands the water pressure without fracturing or developing leaks, it is assumed that it will carry the required steam pressure in safety.

In making the hydrostatic test the pressure must be applied very slowly and carefully, and the gauge watched for any drop of pressure that would denote a yielding of some part of the boiler. New boilers are tested by hydrostatic pressure to reveal leaky joints or rivets. When the seams or rivets are not tight, water trickles out in drops or spins out in a stream. Such places are marked with chalk and afterwards recalked. The insurance companies in most cases depend on the hammer test, but use the hydrostatic test for new boilers, old boilers extensively repaired, and all boilers that cannot be examined thoroughly inside and outside.

A method of applying the hydrostatic test, used by many engineers, is to fill the boiler full of cold water and build a gentle fire in the furnace. As the temperature of the water rises, it expands and thus subjects the shell to pressure. It is urged in favor of this method that the pressure is raised steadily, and the boiler is not as liable to be injured as it is when subjected to sudden and jerky rises of pressure due to the working of a pump. The temperature of the water should

in no case be made to rise above the boiling point at atmospheric pressure, since, if a rupture should take place, the pressure of the water would lower to that of the atmosphere, and the temperature of the water being above the boiling point at atmospheric pressure, a quantity of the water might suddenly flash into steam and cause an explosion.

BOILER EXPLOSIONS

98. A boiler explosion can be caused only by overpressure of steam. Either the boiler is not strong enough to carry its ordinary working pressure, or else for some reason the pressure has been allowed to rise above the usual point. In the first case, the boiler may be too weak for the working pressure because: (1) it is poorly designed; (2) the material or the workmanship may be poor; (3) the parts may have become weakened by corrosion; (4) the parts may have been weakened by careless or reckless management, such as letting cold water come in contact with hot plates, or blowing the boiler off hot and then quickly filling it with cold water.

99. When the pressure rises above its usual point, the fault is probably due to the sticking or overweighting of the safety valve. Some very disastrous explosions have been caused by closing a stop-valve between the safety valve and boiler, while cleaning the latter, and then forgetting to open the stop-valve. It cannot be too strongly urged that a stop-valve should never be placed between the safety valve and boiler. Low water may cause explosions in internally fired boilers, but will rarely cause externally fired boilers to explode.

100. Explosions may be prevented by observing the following directions:

1. Have the boiler inspected or tested to determine its safe working pressure.

2. Use all possible care to prevent internal and external corrosion, and be careful that the plates do not become reduced to an excessive thinness without your knowledge.

3. Do not strain the shell by subjecting it to great changes in temperature; that is, do not blow it off hot and quickly fill up with cold water; do not deluge red-hot plates with cold water, and do not let in more cold air through the furnace door than is necessary.

4. Do not overload the safety valve, and do not let it become corroded fast to its seat.

5. Do not allow the water to get very low.

6. Cases have been known where the sudden opening or closing of a large stop-valve leading to the main steam pipe has led to an explosion. There is much risk in so doing; hence, it is well to open or close such a valve slowly and cautiously.

7. Do not try to use a boiler after it is worn out. Replace it with a new one.

PIPE-FITTING TOOLS

CONSTRUCTION AND MANIPULATION

HAND TOOLS

INTRODUCTION

1. The general character of the pipe fitter's outfit, or **kit**, of tools, as well as the manner in which he handles and cares for them, is frequently considered an index by which the capabilities of the workman may be accurately gauged, and in order to prevent being misjudged it is therefore important and necessary to eliminate habits of carelessness in using, storing, and caring for such implements as are required to do first-class work at all times.

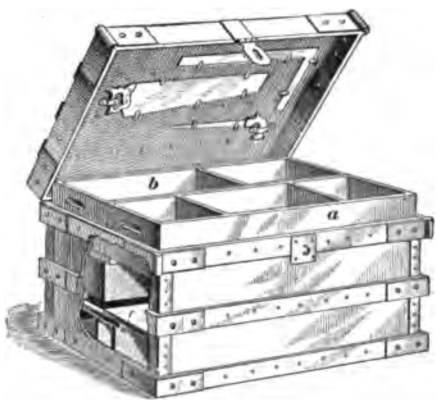


FIG. 1

Tools should be selected with reference to their durability, the element of first cost being of minor importance compared with the long life or period of usefulness of high-grade, and consequently comparatively high-priced, tools, which may be kept in good condition by common-sense handling and the use of enough oil to prevent rusting.

To preserve and care for tools properly, it is necessary to provide suitable storage for them, and this is best secured by using a strong, well-designed tool chest, such as that shown in Fig. 1. There are two trays *a*, *b* for the small tools, such as the taps and dies, chisels, plumb-line, oil can, etc.; the cover is arranged to hold the saws and square, as shown, while the heavier tools are placed in the bottom.

PIPE-JOINING TOOLS

2. Pipe Tongs.—In order that pipes may be screwed tightly into their fittings, it is necessary to employ some device that will tightly grip the pipe and permit the force used in screwing up to be exerted at a considerable distance from the center of the pipe. The simplest device for this purpose is the **common pipe tongs,** shown in Fig. 2. In

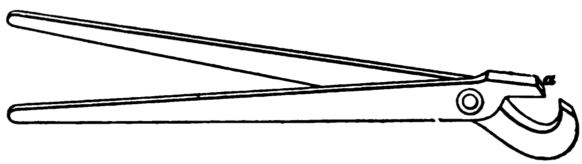


FIG. 2

use, one pair of tongs is placed around the pipe to be screwed up and another pair around the connecting pipe or fitting in the opposite direction; then, as one pair of tongs is pulled forwards, the other pair is pushed backwards or held stationary, and the piping thereby screwed up. The *parrot-nose*, as the bent end on one of the pair of bars that form the tool is called, fits around the pipe, while the other bar has a sharp, flat, short end *a* that bites on the pipe and cuts into it to secure a firm hold; the two bars are riveted loosely together across each other, so that a pressure on both handles clamps the pipe firmly. These tongs are made to fit each standard size of pipe from $\frac{1}{8}$ to $2\frac{1}{2}$ inches, and even larger, in some cases, but their use is not advisable on larger sizes than 2-inch pipe, as they are then too clumsy to handle. It is necessary to have two pairs of each size of the common form

of tongs for each size of pipe; but, on the smaller sizes of pipe adjustable tongs may be used.

3. Adjustable tongs, such as are shown in Fig. 3, are similar to the common tongs except that the clamping bar *a*

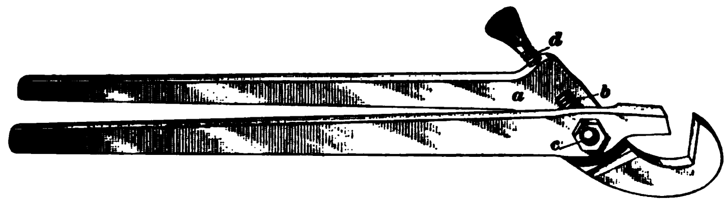


FIG. 3

has a slot *b* with a shifting pin fulcrum *c*, and a screw *d* to shift the fulcrum to suit the size of the pipe to be screwed up. The adjustable tongs are made to take only two or three sizes of pipe and are therefore not as popular as pipe wrenches, which have a wider range of adjustment.

FIG. 4

4. Chain tongs, of which the Robbins and Vulcan types are illustrated in Figs. 4 and 5, respectively, are generally used for screwing up the larger sizes of pipe. They have serrated jaws *a* at one end of a long lever handle *b*, a chain

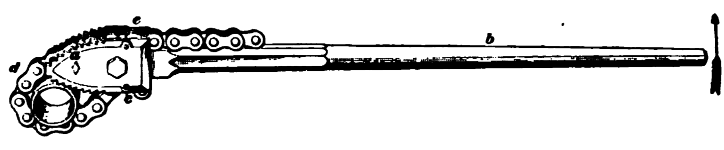


FIG. 5

being fastened to the lever at *c* near the jaws; the chain is passed around the pipe and drawn tight and a link is dropped into a link socket between a pair of lugs *d*, which prevents the chain from slipping and holds the serrated jaws to the

pipe. Pressure on the lever handle *b* forces the jaws into the pipe and with the hold thus gained, the pipe or fitting can be turned. A cable chain is used with the Robbins pipe tongs shown in Fig. 4, and a flat-link chain with the Vulcan pipe tongs shown in Fig. 5.

5. Pipe Wrenches.—While pipe tongs derive their name from their resemblance to the ordinary blacksmith's tongs, which is rather remote in the case of chain tongs, however, **pipe wrenches** derive their name from their

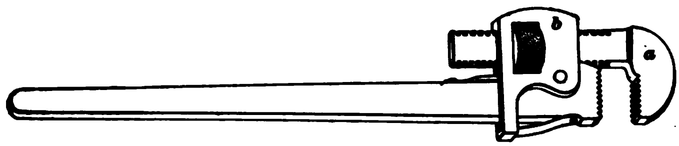


FIG. 6

resemblance to the wrenches used for screwing up bolts and nuts. The *Stillson pipe wrench* shown in Fig. 6 is one of the best-known forms; it has a movable jaw *a*, which is caused to travel through a carriage pivoted to the handle, as shown, by an internally threaded collar or nut *b* that fits the thread on the movable jaw and fits the opening in the carriage, so that by turning the collar the jaw *a* is adjusted

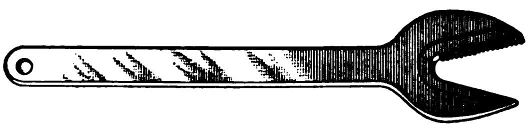


FIG. 7

to fit the pipe. At the end of the handle is a toothed jaw whose teeth are cut in a direction opposite to that of the teeth in the movable jaw, so that the teeth will grasp the pipe firmly when it is to be turned.

6. Alligator wrenches, as indicated by Fig. 7, have a V-shaped opening in one end, or, in the smaller sizes, in both ends. One side of this opening is left smooth and the other side has teeth cut in it, as shown. These wrenches can be applied to all-round objects, and are often used to

grip pipe in places where a satisfactory hold cannot be secured with other forms.

7. **Friction wrenches,** which are especially adapted for screwing up nickel-plated or polished brass pipe, and which are used chiefly by plumbers, usually consist of a smooth, hinged, strap-like clamp, the frictional gripping tension of which around the pipe increases with the pressure exerted on the handle of the tool when the pipe is turned. The strap clamp is of such a width, however, that there is no danger of crushing or otherwise marring the pipe.

8. **Monkeywrench.**—For gripping the hexagonal flanges of brass valves and other similar fittings without marring them, the **monkeywrench,** shown in Fig. 8, is

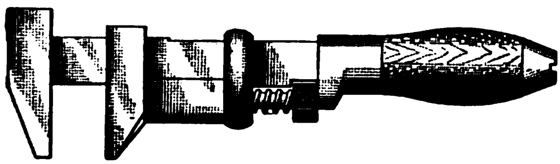


FIG. 8

used. The same tool is also used for screwing up bolts and nuts on pipe flanges and elsewhere. It has a movable jaw, as shown, permitting it to be easily adjusted to the work. Unlike the pipe wrenches, the jaws are smooth inside. Three or four sizes of these wrenches are considered necessary for a well-equipped pipe-fitter's tool chest.

HAND PIPE-CUTTING TOOLS

9. For cutting, by hand, pipe up to 2 inches in diameter a form of pipe cutter extensively used, and known as a **single-wheel cutter,** is shown in Fig. 9. The pipe to be cut rests in the V-shaped recess of the nose, or jaw, *a*. A hardened and tempered steel revolving wheel or knife *b* is mounted in the block *c*, the cutting wheel *b* being forced against the pipe to be cut by turning the handle *d* and thereby screwing up the rod *e*. When the tool is rotated around the pipe, a groove is cut in the pipe to a depth

depending on the squeezing pressure exerted on the cutter *b* by screwing up the handle rod *e*. When the pipe is nearly cut through, it may easily be broken off. To obviate the tendency to the formation of a burr at either side of the cut, and also to reduce the frictional resistance to the turning

FIG. 9

movement of the tool about the pipe, as well as to secure a perfectly true, even hold on the pipe while revolving the cutter, an improved type of single-wheel cutter, known to the trade as the *Saunders pipe cutter*, is provided with two smooth rollers placed in the jaw directly opposite the cutter wheel.

10. Two-wheel and three-wheel pipe cutters are similar to the single-wheel types, except that they have two and three hardened and tempered steel cutting wheels instead of one. In the three-wheel cutter, illustrated in Fig. 10, the two cutting wheels *a* and *b* are pivoted in the jaw of the frame *c*, while a third wheel *d* is mounted in the adjustable arm *e*, which in turn is pivoted to the frame *c*, as shown.

FIG. 10

The long boss at the right of the frame *c* is tapped to receive a handle *f*, by turning which the wheel *d* and arm *e* may be caused to move toward or away from the pipe. In applying a three-wheel cutter, care should be taken to hold the tool square with the pipe; otherwise, the wheels will cut several grooves instead of one, and should the wheels slip from one groove to another, their cutting edges are liable to break.

This difficulty is not experienced with the single-wheel tool, but the latter does not cut the pipe so quickly. The three-wheel cutter is an especially convenient tool for cutting pipes in closely confined spaces, where it is impossible to swing the cutter entirely around the pipe. There are certain cases, occurring notably in cutting pipes in trenches, where the three-wheel cutter can be used to better advantage than the single-wheel or two-wheel type, and there are also places where neither tool can be used, and then recourse to the hack saw is necessary.

11. Oil should be freely used in cutting pipe, and the edges of the cutting wheels should be kept sharp; if dull, they will not cut properly, but will force the pipe inwards, as indicated at *a*, Fig. 11, thereby forming an internal burr and reducing the bore of the pipe at *a* so as to obstruct the flow of steam or water through the pipe. Even with sharp wheels there will be a small burr, which always should be removed. After cutting off a piece of pipe, the cut ends should be examined to see whether any cracks or splits have been started by the cutting operation.

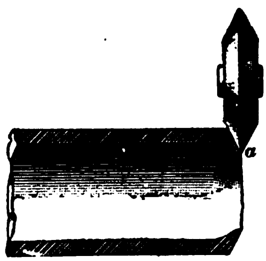


FIG. 11

In cutting pipe, the helper places the pipe cutter in position on the mark, tightening the handle to force the cutter into the pipe. The fitter and helper now face each other, as indicated in Fig. 12. The former draws down the lever handle of the tool on one side, while the latter draws it up on the other side, thus revolving the tool around the pipe. At each revolution, the handle is screwed up to force the cutter deeper into the pipe and the turning operation is repeated, enough oil being used to reduce friction, until the pipe is cut.

diameter in his tool box, and as they are costly, delicate tools to carry in the tool box, as far as possible the reaming should be done in the shop.

FILES AND FILING

13. Kinds of Files.—Files are frequently needed to smooth down the ridges left by hand pipe cutters, and they are put to many other uses by the fitter. The files commonly used by fitters are the *half round*, *round*, *flat*, and *saw* files. The half round file is generally used on pipe, as the round part, which is a segment of a circle, can be inserted in the pipe for removing burrs, etc., and the flat part can be used on the outside; this file should be what is known as a *second-cut file*, that is, it should have its teeth of the coarseness indicated by Fig. 16, which illustrates the relative coarseness of the cut of 16-inch and 4-inch files, respectively, side by side.

FIG. 16

The flat file, shown in Fig. 17, is intended for touching up places that are roughened by the tools; this should be a *fine-cut file*, that is, have fine teeth. The round file is used for small pipe and where round openings in castings or other

FIG. 17

work are to be filed out so that a tap or reamer may enter, or for any other purpose; it should be a smooth second-cut file. The saw file should have a fine cut, and be triangular in shape; it is used to sharpen saws, or cut nicks in the work where required.

14. Filing.—No attempt should be made to keep the body rigidly in one position while filing, especially on heavy work. A free, easy motion of the body, in the direction in which the file is moving, permits a greater force to be exerted without undue strain. In filing right-handed, the workman

stands with his left foot toward the work, and as the file is moved forwards, a slight bending of the left knee will tend to throw the body against and on the file, thus assisting in making the cut. During the return stroke, the knee is straightened as the body returns. A little practice will show the extent to which this motion of the body can be made to assist in the work. The height at which the work should be held depends largely on the class of filing that is to be done. Ordinarily, the surface to be filed should be about as high as the elbows of the workman. When the work is extremely heavy, it should be set somewhat lower, in order that a greater pressure may be put on it. If the vise or supporting device is too high, a foot-board or low bench may be used to stand on. The feet of the bench should be set flush with the ends of the board, in order to prevent tipping when stepping on the ends.

15. The effect of oil on filing varies greatly with different metals and different classes of work. In finishing broad, smooth surfaces of cast iron, the presence of oil prevents the file from cutting and causes it to slip over the surface, thus wearing off the sharp points of the teeth. On cast iron, generally, and especially on the class of work just mentioned, oil should never be used. On the other hand, it may sometimes be advantageously used when filing wrought iron and steel and other hard fibrous materials, especially in finishing surfaces, when the file is new and sharp. Oil prevents the file from scratching and cutting too deeply. Sometimes the teeth are filled with chalk, either dry or mixed with oil; this, to a great extent, prevents the filings from clogging between the teeth. New files are usually sent from the factory covered with oil, to prevent their rusting. For work in which oil on a file is objectionable this oil must be removed, which is sometimes done by first rubbing off the surplus oil and then coating the file with chalk and brushing it off carefully.

16. One of the most serious troubles to contend with in filing is the tendency to *pin*. The cuttings clog between the

teeth, forming hard, sharp points that scratch the material. This is known as **pinning**, and occurs more readily in some materials than in others. As soon as the slightest indication of pinning is observed, the teeth of the file should be carefully cleaned. Sometimes this may be done by rapping the file against a wooden block or the work bench, or by rubbing the hand over it. In most cases it is necessary to use a wire brush, called a *file card*. Vigorous brushing in the direction of the cut of the teeth usually removes the pins, but in cases where the brush will not remove them, a piece of soft sheet brass, or copper, or iron wire flattened out at one end, may be used. The end is pressed crosswise on the teeth, and moved in the direction of the length of the teeth. Little grooves will be cut into the soft metal, forming small teeth that clean the file thoroughly.

17. Selection and Care of Files.—The life of a file may be prolonged very materially by exercising care in selecting a suitable one for each piece of work, and in using it properly. A new file should never be used on rough cast iron from which the sand and scale have not been removed, nor on narrow surfaces. Both these conditions tend to break and dull the teeth. A well-worn file will do excellent service in both these cases. On narrow work, a worn file will give better results than a new one, the teeth on a new file being so sharp that the few teeth in contact will enter so deeply that they are liable to be injured and to scratch the work. A new file should be used first on brass or wide surfaces or smooth cast iron.

Files should never be thrown upon one another, or upon tools or other hard substances. In too many cases files, hammers, cold chisels, wrenches, and tools of all kinds are thrown into a tool box or cupboard promiscuously, resulting in injury to the files and other cutting edges, to say nothing of the generally careless and dilapidated appearance of the tool box and shop and the time wasted in trying to find anything that is wanted. A tool box or cupboard should always be kept in order. There should be "a place for everything

and everything in its place" when not in use. Files should be laid either on shelves or in a drawer provided with small divisions so that they will not rub against one another. They should always be carefully cleaned before they are put away, and kept in good condition, so as to be ready for use when they are required.

HAND THREADING TOOLS

18. Definitions.—The operation of cutting a screw thread on the outside of a cylindrical or other piece of work circular in cross-section, that is, the cutting of a male thread, is called **threading.** In pipework, threading follows the cutting of the pipe into proper lengths, the pipes being threaded by means of tools called **stocks** and **dies,** the latter name being that by which the cutting parts are known, while the former is the name given to the die-carrying part of the tools, which are of various shapes and sizes.

19. Die Stocks and Dies.—The ordinary form of die stock employed in threading pipe by hand is shown in Fig. 18. The stock consists of a malleable-iron frame or body that carries the die *a* and into which are screwed the arms *b* and *c* for revolving the stock around the pipe. The die is placed in the square recess at *d*, over which slides a cover that serves to hold the die in position. That part of the frame which is slipped over the end of the pipe has a guide *e* that moves in a threaded socket whose threads have the same pitch as those of the thread to be cut by the die. The guide *e* has three or more setscrews *f*, *g* for rigidly clamping it to the pipe and thus preventing the guide from turning. The rotation of the stock screws it up on the rigidly clamped guide *e*, thus pulling the die forcibly against the end of the pipe to start the thread; but, when the latter has been well started the setscrews may be loosened, if desired, and the threading finished without further use of the feed given by the threaded guide. The largest pipe on which a thread may be cut by the tool described is one whose outside diameter is a trifle less than the diameter of

the hole through the guide *e*. The smaller pipes, however, may be threaded by using different sizes of bushings, as *h*, Fig. 18 (*c*), whose inside diameter is a trifle more than the outer diameter of the pipe to be threaded, and whose outside diameter is practically the same as the inside diameter of the guide *e*, the bushings being held in place by setscrews *f*, *g* that pass through them. The bushings and dies are changed to suit the diameter of the pipe to be threaded.

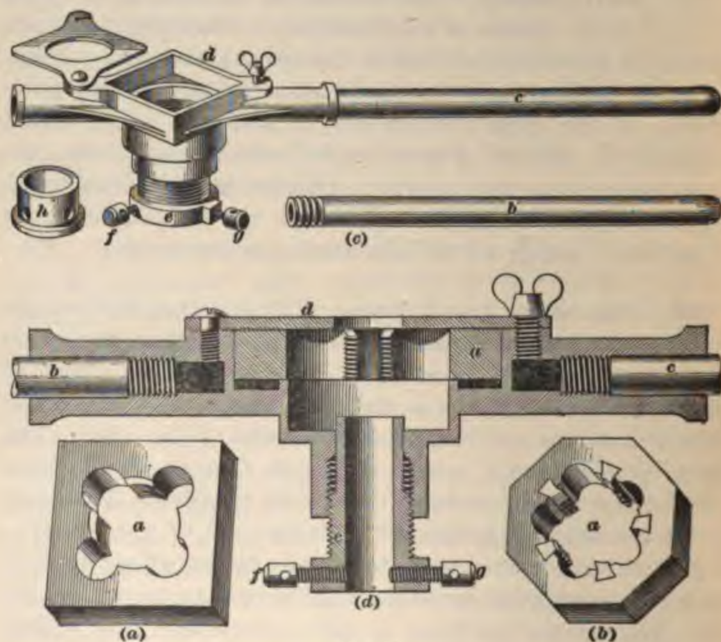


Fig. 18

20. The die stock shown in Fig. 18 employs solid dies, made in the smaller sizes of one piece of tool steel, as illustrated by Fig. 18 (*a*), and in the larger sizes made of a machinery steel or cast body with inserted tool-steel cutters, as shown by Fig. 18 (*b*). The die being solid, a full thread is cut in one operation. Obviously, a solid die can only cut a screw thread equal to its own diameter. Furthermore, the force required to turn the die stock when threading the

larger sizes of pipe becomes excessive when a solid die is used. In addition, one-piece solid dies cannot be readily sharpened when they have become dull. This objection is partly overcome in the die with inserted cutters, which can be driven out for sharpening. To overcome the objections to solid dies, die stocks having adjustable dies have been designed and are widely used. These dies can be sharpened very readily, being easily removable and of a shape to permit sharpening without special appliances; futhermore, the fact of their being adjustable permits threads to be cut to fit threaded holes with any desired degree of tightness. Dies are expensive, and hence they should have

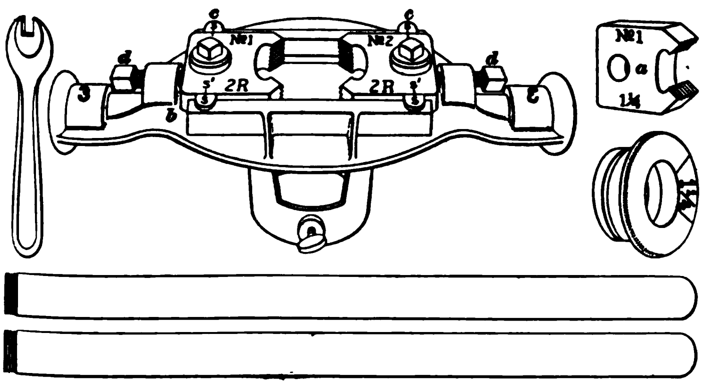


FIG. 19

the best of care, and be kept in cases such as the manufacturers make for them, together with the die stock. Dies are made with right-hand or left-hand threads, so that either can be placed in the stock as may be required.

21. A die stock with adjustable dies, and known as the *Armstrong*, is shown in Fig. 19. It is provided with the usual arms or handles for turning and thimbles or bushings for centering the pipe and guiding the dies. The dies *a* are held in the stock *b* by means of the clamp screws *c*, *c* and are adjusted to cut larger or smaller than the standard by the adjusting screws *d*, *d*. Lines *s*, *s* are cut in the stock and corresponding lines *s'*, *s'* are placed on each die, in such a position

that when these lines coincide the dies are properly set to cut the pipe to the standard size.

22. Hand stocks like those shown in Figs. 18 and 19 are not ordinarily used for pipes larger than 2 inches. Larger sizes of pipe are, however, threaded by using large die stocks having four arms to permit of shorter strokes by the men who operate them, but as a rule large pipe is threaded at the shop in threading machines driven by means of a hand crank or by other power. As such machines are not easily moved from job to job, large four-arm die stocks, such as that illustrated in Fig. 20, having adjustable sectional dies capable of threading and cutting off pipe up to 8 inches in diameeter, have been designed. The sectional dies *a*, *a* are held

FIG. 20

in position in the frame of the stock by means of clamping screws *b*, *b*, the dies being adjusted by means of setscrews *c*, *c* to the sizes of pipe within the range for which the tool may be designed. A cutting-off tool is provided within the knife case *d*, the knife being moved in or out by means of a T-handle feed-screw that passes through a threaded lug of the stock frame on the under side of the knife case. When pipe is to be cut off, the dies are removed and guides *e*, shown at the right of Fig. 20, are placed in the die slots. Bushings *f*, held in position by thumbscrews *g* whose ends project into the groove *h* of the bushing, are used as guides. These bushings are made to suit different diameters of pipe.

23. A **self-centering adjustable die stock** for cutting off and threading pipes is shown in Fig. 21. The die can be adjusted by unscrewing the thumb nuts *b*, *b* and then rotating the cam-plate *c*, which engages the slots in the dies *d*, shown separately at the right. When the cam-plate is so adjusted as to bring the characters *o*, *o* in line, the grooves or openings in the under side of the cam-plate will be directly over the slots in the dies, and the dies may be inserted or removed. The pipe-cutting knife is moved in or out by the handle *e*, and is easily removed for sharpening. The guides (not shown) are adjusted to fit the pipe by a cam-plate *f* in the same manner that the dies are adjusted. The levers *g*

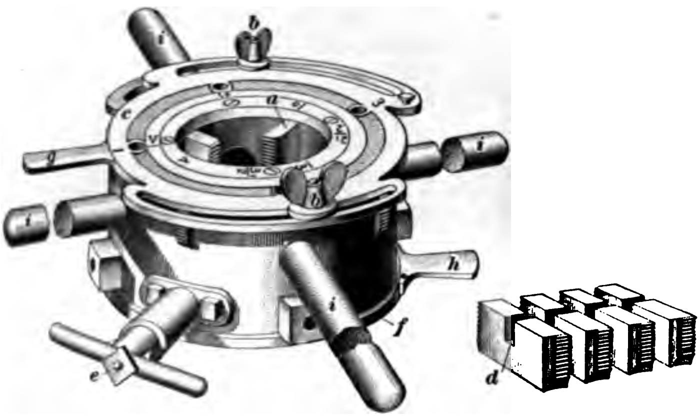


FIG. 21

and *h* are used for moving the cams *c* and *f*, respectively. The stock has four arms, as *i*, *i*. The principal advantage of the cams in the cam-plate is that they can push in or pull full out all the dies, or all the guides equally, without changing the alinement of the tool. It is therefore not only adjustable but also self-centering. The construction also allows the fitter to remove the dies after a thread has been cut without running the dies back over the thread. Each set of dies is adapted to thread four sizes of pipe. Large pipe can be threaded by taking two or more cuts. Guide marks for setting the dies for cutting different sizes of pipe are shown on the face of the cam-plate.

24. A **ratchet stock** is a very handy tool for threading the end of a pipe where it is impossible to swing common dies, as, for example, in a trench, or in the corner of a cellar where a pipe projects too far and requires to be cut off close to the wall and threaded while in place. A ratchet stock is shown in Fig. 22. The lever handle *a*, when screwed down tightly, is used to hold the pipe steady between the jaws *b*, *b*, while the die is turned by working the long handle *c* backwards and forwards. After the thread is cut, the die is reversed by shifting a pawl *d* near the base of the long handle, which pawl operates the ratchet *e*.

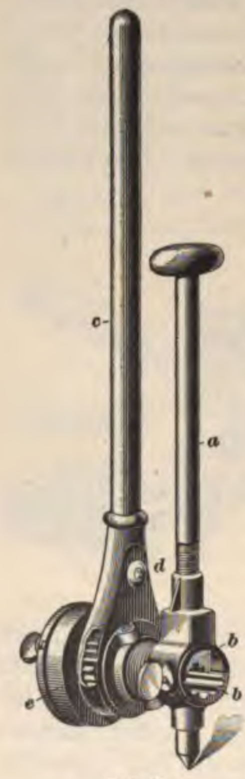


FIG. 22

25. Besides threading the ends of pipe, the fitter is frequently required to cut outside threads of different pitches by hand, various forms and sizes of dies being used to cut threads on pieces from $\frac{1}{16}$ inch to 2 inches in diameter. A suitable form of stock and die that has many advantages for such work is shown in Fig. 23 (*a*). The stock *a* has an opening *b* provided with guides for holding the dies *c*, *c*, which are closed by a setscrew. The form of these dies is shown in Fig. 23 (*b*). They are so constructed that the cutting is done at the points *f*, *f*. Bolts can be threaded standard, under size, or over size with these dies. For example, a No. 14 machine screw, which is .24 inch in diameter, a $\frac{1}{4}$-inch, or a $\frac{9}{32}$-inch screw, all 20 threads per inch, can be cut with one pair of dies. The dies can be obtained for all standard sizes and pitches of screws and bolts. They are especially adapted to repair work where the variety of work is great and the quantity small. With these dies, several cuts must be taken

o cut a full thread. A pair of blank dies with suitable ıotches cut in them, used in this stock, makes an excellent ap wrench.

26. Use of Die Stocks and Dies.—The tightness of a ;crew joint depends largely on the accuracy with which the hread is cut. A good thread is shown in Fig. 24. The

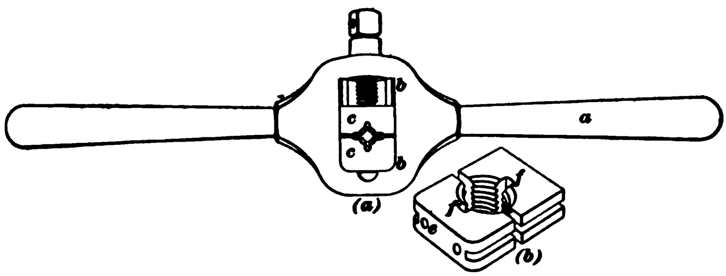


FIG. 23

ɔart *a* contains the leading threads, which are perfect in orm. These are depended on chiefly for making a close :ontact with the thread in the fitting, and thus insuring a ight joint. The threads at *b* are imperfect. Their tops are lat and they serve only to make he joint rigid, unless their form be :hanged by the pressure exerted n screwing the pipe into a socket ɔr fitting.

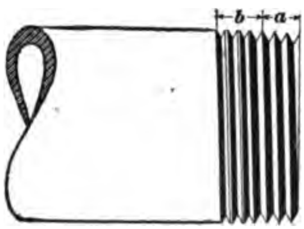


FIG. 24

Occasionally a groove runs engthwise in a wrought-iron pipe; his prevents a perfect thread being nade. Such pipes should not be ısed on high-pressure work. On low-pressure work, how-:ver, they may be used, provided that they are screwed up vith red-lead cement and hemp wrapped over the thread, ıuch materials filling the interstices and making the joints ight enough for low pressures.

27. The majority of manufacturers of wrought-iron pipe ave adopted the *Briggs standard system* of screw threads for

pipes and fittings. A few manufacturers, however, do not conform to it strictly; they use 12 threads per inch instead of the $11\frac{1}{2}$ threads called for in Table I. All pipe ends are made conical by the threading process, the taper being $\frac{3}{4}$ inch per foot of length, or 1 in 16, as it is often expressed.

To make perfect joints with standard fittings, the perfect threads should be cut only to a certain distance from the end of the pipe. This distance, as well as the standard number of threads per inch, is given in Table I.

TABLE I

SCREW THREADS FOR WROUGHT-IRON PIPE

Nominal Internal Diameter Inches	Number of Threads per Inch	Length of Perfect Threads Inch	Nominal Internal Diameter Inches	Number of Threads per Inch	Length of Perfect Threads Inches
$\frac{1}{8}$	27	.19	2	$11\frac{1}{2}$	.58
$\frac{1}{4}$	18	.29	$2\frac{1}{2}$	8	.89
$\frac{3}{8}$	18	.30	3	8	.95
$\frac{1}{2}$	14	.39	$3\frac{1}{2}$	8	1.00
$\frac{3}{4}$	14	.40	4	8	1.05
1	$11\frac{1}{2}$	.51	$4\frac{1}{2}$	8	1.10
$1\frac{1}{4}$	$11\frac{1}{2}$	.54	5	8	1.16
$1\frac{1}{2}$	$11\frac{1}{2}$	.55	6	8	1.26

28. Solid dies are commonly used for threading small pipes. The dies are slipped over the cut end of the pipe *a*, as shown in Fig. 25. There being no setscrews on the guides of the small stocks, it is necessary to start the thread by pressing the die tightly against the end of the pipe while revolving the stock slowly. After the die has caught a firm hold of the pipe, the pressure against the end is relieved, the pipe end is heavily oiled where the thread is to be cut, and the stock is revolved steadily until the die has traveled far enough to make the required length of perfect thread on the pipe. While the thread is being cut, it should be periodically oiled and the dies thus kept cool. If this is neglected, the

dies will soon be ruined, the thread will be ragged, and the workman will waste a great deal of energy in the threading operation. A good grade of heavy-body machine oil is best adapted for threading pipes. Kerosene, water, etc. are useless. After the thread has been cut, the helper should blow all the chips out of the dies and then run the dies off the pipes.

29. If solid dies, 2 inches or less, cannot be started by the pressure of the body, the cause may be due to a burr on the end of the pipe, dull dies, or the man at the dies does not

FIG. 25

know how to work them. The proper method of starting dies that do not have a threaded bushing for starting them is to place the dies squarely against the end of the pipe, throw the full weight of the body against the stock, and at the same instant turn the handles a few inches, the motion being repeated several times until the force required to move the handles becomes too great for a man in a position facing the end of the pipe. The handles should not be moved

between the jerks necessary to start the thread; otherwise, the thread will be stripped, and it will be a much more difficult matter to start a new one. Fig. 25 shows the attitude that should be taken by the fitter in starting a thread without the aid of a threaded guide bushing. The arrow shows the direction of the travel of the stock. A **V**-shaped support holds the pipe *a* steady and in line with the vise. After the thread is started, the remainder of the thread is cut by simply revolving the die stock. There is a knack in pulling and pushing dies so as not to rack the body by the heavy strains accompanying this work, the object sought being to exert a minimum amount of energy for the amount of work to be done. Some fitters cut and thread pipes with apparent ease, and the work does not seem to affect them; they retain their good form through continuous years of service, while others become more or less rapidly incapacitated for such work. In cutting threads, the art of making labor light lies in training oneself to assume attitudes that will distribute the heavy strains over the whole framework of the body rather than on a few muscles. In threading pipe, after the thread has been started, the dies should not be revolved in jerks; a steady movement is desirable, but, of course, it is impossible to get a continuously uniform speed of the dies in threading by hand because the position of the hands must be changed at different positions of the die-stock handles. The motion should, however, be as nearly uniform as is possible and consistent with speed.

30. Fig. 26 serves to illustrate the threading operation when two men operate the dies, as is necessary in threading the larger sizes of pipe. In Fig. 26 (*a*) is shown the starting of the thread. The helper at the left is throwing himself forwards to force the dies against the end of the pipe, and is assisted by the pipe fitter at the right drawing the dies toward the end of the pipe, as shown. Fig. 26 (*b*) illustrates the position assumed in threading when the die-stock handles are slightly beyond the horizontal position. The helper is pushing upwards with his left hand and drawing downwards with

his right hand; the pipe fitter is throwing his weight on his right hand and drawing upwards with his left hand. When the position shown in Fig. 26 (*c*) has been reached, the helper and pipe fitter change holds, as shown in Fig. 26 (*d*), the helper pulling upwards and the pipe fitter downwards until near the position shown in Fig. 26 (*b*), when they change their holds to the positions shown. If both men do

(*a*) (*b*) (*c*) (*d*)

FIG. 26

not pull together and in harmony, the work will be severe on the more energetic man. When a fitter finds a helper that works in harmony with him at the vise, he should continue to use that helper, if possible, and not make a change.

The manner in which a four-armed die stock is used for threading large pipe, say 3 inches nominal diameter, is illustrated in Fig. 27. The die stock is operated by three men

standing in the position shown, or by four men, two on each side.

31. Taps.—The operation of cutting internal, or female, threads by tools screwed into the hole to be threaded is called

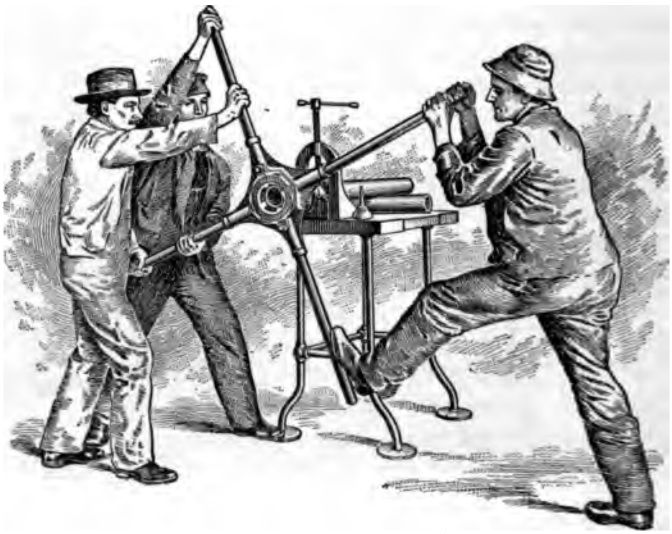


FIG. 27

tapping, and the tool used is known as a **tap.** The only taps used by pipe fitters, as a general rule, are *pipe taps* and *machinists' hand taps.*

A common **pipe tap** is shown in Fig. 28. The threads *a* are tapered and conform to the standard pipe thread. The flutes *b*, by which cutting edges are formed, also serve as channels by which the cuttings can escape. In order to insure tight joints with all kinds of pipework, it is

FIG. 28

necessary that the holes to be tapped should be slightly tapered, and a tapered reamer is therefore used to give them the requisite conical form before the tap is entered. The

standard taper for the threaded portion of pipe taps is $\frac{1}{16}$ inch to the inch; or in other words, $\frac{3}{4}$ inch to the foot. The holes to be tapped for small sizes of pipe are usually drilled to

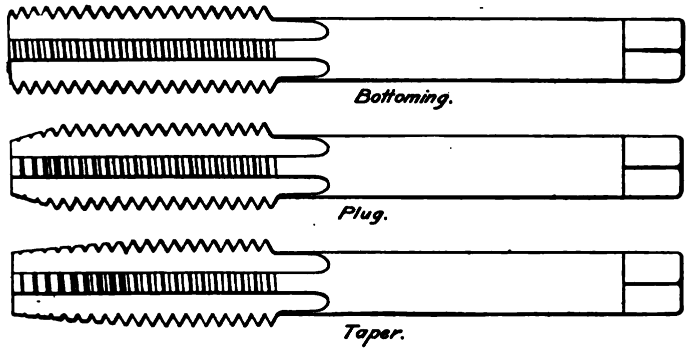


FIG. 29

the size of the bottom of the thread at the small end of the tap, and the pipe tap run down to the proper depth; but for large work, a reamer having the same taper as the tap is run in to take out some of the stock. This reaming leaves the proper amount of stock for threading and saves unnecessary wear of the tap. Pipe taps are also often used for recutting and straightening bruised threads in malleable iron and other fittings.

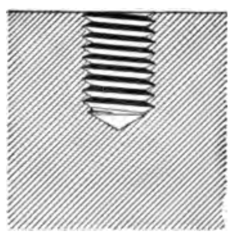
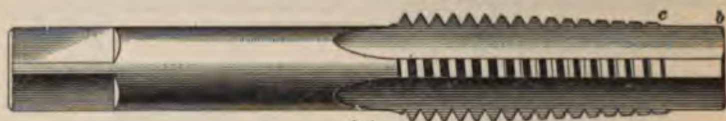


FIG. 30

Machinists' hand taps are useful to the fitter in tapping or retapping holes for screws, bolts, etc. in repair and other work. A full set of a single size of such taps is shown in Fig. 29, consisting of a *taper tap*, a *plug tap*, and a *bottoming tap*.

32. Tapping.—When a hole has been drilled entirely through a piece, it is only necessary to use the taper tap, which may be run entirely through the hole being tapped. When a hole partly drilled through a piece is to be threaded to the bottom, as shown in Fig. 30, it is necessary to use all three taps. The thread is started by using the taper

tap, which is screwed in until it touches the bottom of the hole. The plug tap is next used, cutting full threads somewhat deeper as it is screwed to the bottom of the hole, while



(a)

(b)

FIG. 31

for finishing, the bottom tap is used, thus cutting the full threads to the bottom of the hole.

33. Two kinds of hand taps are in common use. The first, shown in Fig. 31 (*a*), is made with a cylindrical end *b c* having the size of the bottom of the thread. This cylindrical end fits the hole made by the tap drill, so that by the exercise of a little care on the part of the user, a squarely tapped hole is the result. The other kind, shown in Fig. 31 (*b*), is tapered from *d* to *e*; consequently, it will not stand squarely with the hole. To tap a hole squarely, the tap should be well oiled, placed in the hole, and given two or three turns with a double-ended wrench. Then remove the wrench and apply a square to

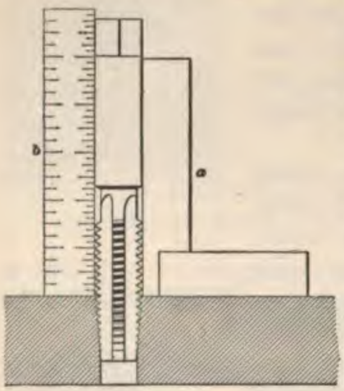


FIG. 32

the tap in the manner shown at *a*, Fig. 32. Try the square at the next flute, and if the tap shows out of square, apply pressure enough sidewise on it with the wrench while turning

to bring it square with the surface. Repeat these trials until the tap is found to be square. If a square is not at hand, a wide 6-inch steel rule may be used instead, as at *b*, Fig. 32. The tap shown in Fig. 31 (*a*) will go in reasonably straight, but the beginner will do better work with it by using the same precautions as with the other style.

34. The tapping jig shown in Fig. 33 is sometimes used. It consists of a piece of iron or steel bent to the form shown at *a*, Fig. 33 (*a*). The bottom surface *b c* is planed flat and

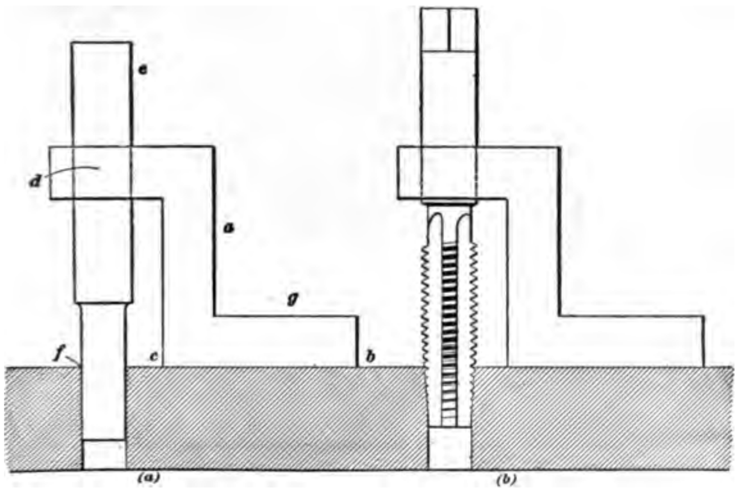


FIG. 33

a hole *d* the size of the tap shank is drilled at right angles to *b c*. A plug *e* is turned to fit *d* and the hole *f* to be tapped. To use this tool or jig, put the plug into the hole *d* and then push it into *f*, as shown; clamp the leg *g* of the jig *a* to the work, and see that the plug *e* fits easily in both holes; remove the plug and replace it with the tap, which will be held in the correct position to tap the hole, as shown in Fig. 33 (*b*). The hole *d* in the jig may be made as large as the largest tap that can be used with it, bushings being made to fit it for using taps having smaller shanks.

35. Ordinary holes in thin stock may be tapped in one operation by running the taper tap clear through the piece, but if the hole is of great depth, or of hard material, a second, or plug, tap must be run down to relieve the taper tap. By using these two taps alternately, holes may be tapped to any depth that the taps may reach. Neither the taper nor the plug taps will thread a hole clear to the bottom, so when this is necessary the third, or bottoming tap, is screwed clear to the bottom of the hole. Care should be taken in using this tap, as the end teeth are easily broken by the heavy cut.

DRILLING

36. Hand Tools for Driving Drills.—For turning taps and reamers, as well as drilling by hand, a tool known as the **ratchet,** of which Fig. 34 illustrates one type, is employed.

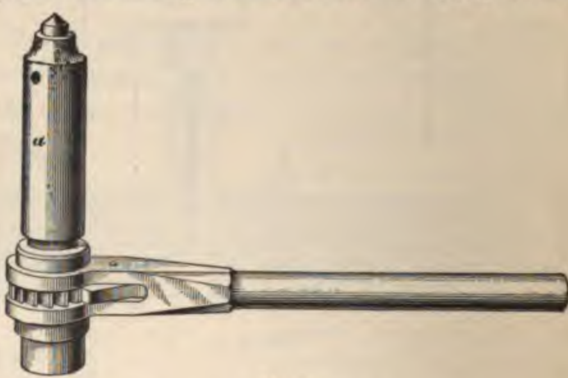


FIG. 34

Ratchet drilling is the slowest method of drilling holes and should not be resorted to if the work can be done by machines such as the drill press, portable drill, or pneumatic drilling machine; but there are places where none of these can be used or are available, and in which cases the ratchet must be used. Ratchets are generally made single-acting; that is, the drill cuts only during the forward stroke of the handle; but some of the improved ratchets are made to give a forward rotary motion to the drill or cutter during both strokes.

In using a ratchet for drilling, the center of the hole to be drilled is plainly marked with a punch having a pointed conical end, and called a **center punch**. The ratchet and drill are supported in the correct position by a suitable clamp rigidly attached to the work, the clamp being called both an **old man** and a **drilling crow**. The drill is usually forced into the work by unscrewing the internally threaded sleeve *a*, Fig. 34. The clamp is made in many ways, varying from a piece of flat iron or steel bent in a suitable form to well-designed adjustable types. One form of adjustable crow is shown in Fig. 35, the work to be drilled or tapped being held in the V-shaped jaws of the brace, the drill being forced into the work by the screw at the opposite end.

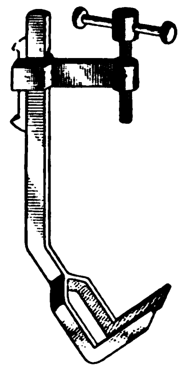


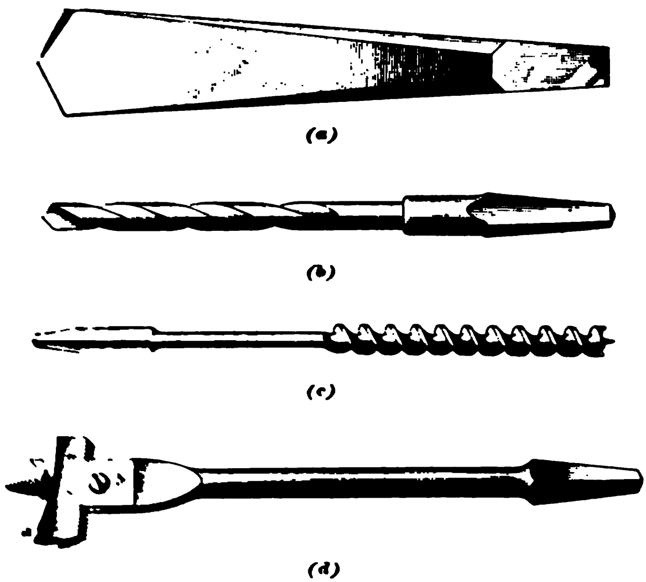
FIG. 35

37. The common **ratchet brace** used by carpenters is also one of the handiest devices for pipe fitters' use, as it can be used in corners and other confined locations. Its use is limited to the drilling of small holes in metal, and to carpenters' wood bits. For work, the drilling of which requires the exertion of a greater force than can be applied to the ratchet brace, the ratchet, Fig. 34, is used.

38. The breast drill, so named from the fact that it is provided with a suitable guard that may be placed against the breast while drilling, is sometimes used by the fitter for drilling small holes in metal and wood, the feed being obtained by a pressure brought to bear on the drill by the body. The drill is usually operated by means of a crank geared to the drill spindle by bevel gears. This style of drill is very largely used for drilling small holes for attaching name plates, and for similar light work.

39. Drills.—Ratchets are made with sockets to receive either square-shank or taper-shank drills. In repair and other work it often happens that an odd size drill, that is, one differing from the regular standard size obtainable in the

market or available, is required. In that case a **square-shank flat drill,** shown in Fig. 36 (*a*), can be made by any blacksmith or by the fitter himself; or, on the other hand, an old flat drill may be made into the required size in a few minutes, either by grinding or dressing. For all standard-size holes, regular twist drills, which may be bought in the market, should be employed. These will drill a better hole than flat drills and with less exertion.



(*a*) (*b*) (*c*) (*d*)

Fig. 36

For use with the ratchet brace, either **square-shank** or **straight-shank twist drills** are employed, the advantage of the square-shank drill, shown in Fig. 36 (*b*), being its non-liability to slip in the brace while drilling. Twist drills, while especially made for drilling metals, can be used for drilling small holes in wood and other soft substances.

40. For drilling through wood, the ordinary **carpenter's bit,** shown in Fig. 36 (*c*), and the **extension bit,** shown in Fig. 36 (*d*), are best adapted. The extension bit can be

adjusted to cut different sizes of holes by loosening the setscrew *b*, adjusting the knife *a*, and then tightening the setscrew again. The bits commonly used by the fitter are those that come nearest to the pipe sizes, such as $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, $1\frac{1}{8}$, and $1\frac{3}{8}$-inch; for cutting larger holes, the extension bit is used.

Before cutting holes in the flooring or walls of frame buildings, the fitter should know exactly where the pipe will

FIG. 37

run, so as to avoid obstructions. Small holes should be cut through in searching spaces concealed from view, the holes being made by using a **search gimlet**, such as is used by electricians for boring holes through which to run wires.

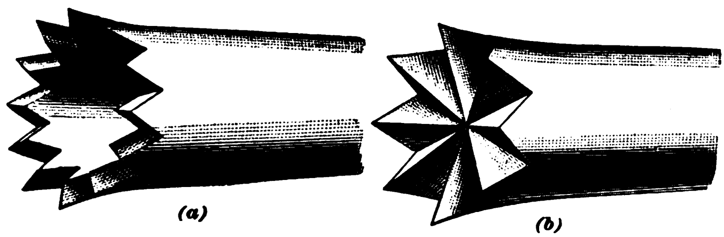
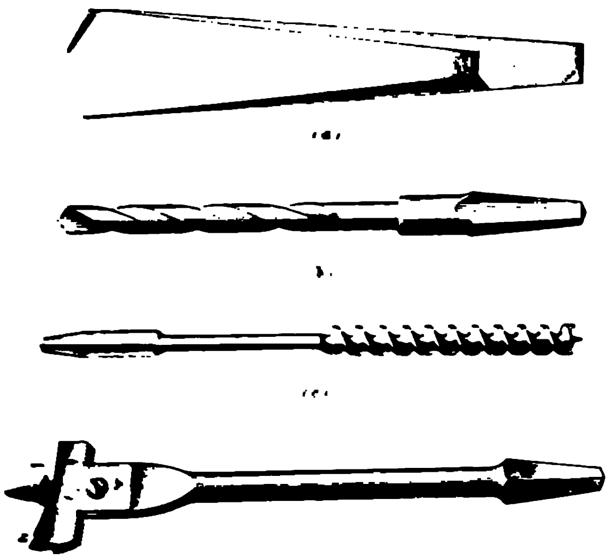


FIG. 38

Such a search gimlet is shown in Fig. 37. It is advisable for a pipe fitter to have a short gimlet and a long one, say about 24 inches in length, in his tool box.

41. Fig. 38 shows two kinds of drills, sometimes called **brick drills,** or **jumpers,** for cutting small holes in brick or stone walls. If the material to be cut is soft brick, the fitter can make a jumper, as shown in Fig. 38 (*a*), out of a piece of steel pipe. One end has a number of teeth filed in it

market or available is required. In that case a squa shank flat drill, shown in Fig. 36 (a), can be mad any blacksmith or by the fitter himself; or, on the o hand, an old flat drill may be made into the required in a few minutes either by grinding or dressing. Fo standard-sized holes regular twist drills, which may be bo in the market, should be employed. These will drill a h better than flat drills and with less exertion.



(a)

(b)

(c)

(d)

FIG. 36

For use with the ratchet brace, either **square-shank straight-shank twist drills** are employed, the advant of the square-shank drill, shown in Fig. 36 (b), being it will not slip in the brace while drilling. Twist dri while especially made for drilling metals, can be used drilling small holes in wood and other soft substances.

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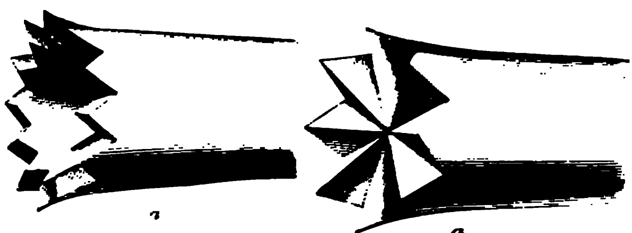
Before cutting holes in the flooring or walls of frame buildings, the fitter should know exactly where the pipe will

Fig. 37

run, so as to avoid obstructions. Small holes should be cut through in searching spaces concealed from view, the holes being made by using a **search gimlet**, such as is used by electricians for boring holes through which to run wires.



(a) (b)

Fig. 38

[illegible] gimlet is shown in Fig. 37. It is advis[illegible] [illegible] and a long [illegible] [illegible] in length [illegible]

41. Fig. 38 shows two [illegible], sometimes [illegible] brick **drills**, or **jumpers**, [illegible] small holes in [illegible] walls. If the material [illegible] be cut is [illegible] [illegible] make a jumper, as shown in Fig. 38 [illegible] piece of steel pipe. One end has a number of teeth [illegible] in it

and the other end should be protected by a cap. Each blow of the hammer makes these teeth cut out some of the brick. To prevent the jumper from being jammed in the hole, the teeth should be spread out a little with a drift pin, so that the hole will be cut slightly larger than the pipe. A common form of jumper, made from a piece of bar steel, is shown in Fig. 38 (*b*). The cutting head is made larger in diameter than the bar to give clearance for the dust. The teeth are filed out and hardened and tempered. With these tools it is possible to cut round holes in stonework, which cannot be easily done with common chisels.

FIG. 39

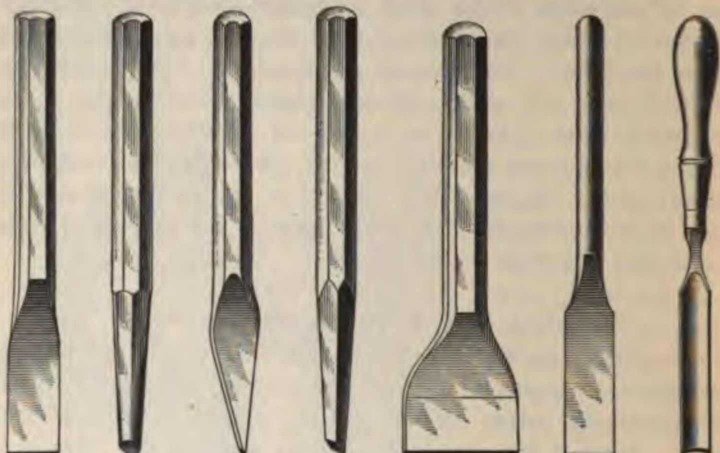
In pipe-fitting work, holes are cut through brick and stone walls to let pipes pass through, and holes are drilled into brick and stone walls to receive pipe hangers or other attachments. Large holes are usually cut through walls with a cold chisel and hammer. Having marked the place where the hole is to be cut, a short piece of plank is braced firmly against the other side of the wall, opposite the place marked, to prevent breaking the brick away when the hole is almost cut through. The same precaution should be taken when a jumper is used. A hole somewhat smaller than the required size is then cut with the chisel and trimmed out to the desired size; if a pipe sleeve is

to be inserted, it is blocked in position and the space around it filled with mortar. Whenever possible, openings for pipes should be left in brick walls when the building is being put up, the openings being fitted with pipe sleeves of sufficient strength to bear the strain of the wall, and large enough to allow the pipe to slip through them easily. To provide for such holes is not always possible, and therefore the holes frequently have to be cut or drilled out. Cutting the opening with a chisel mars the wall and at the same time makes a ragged hole. A brick drill applied in the manner shown in Fig. 39 will make the best job whenever the hole is of such a size that it can be cut by its use.

GENERAL SMALL TOOLS AND SUPPLIES

42. Cutting Tools.—To enlarge openings, to cut beams and other obstructions to allow the passing of pipes through them, and for other similar cutting purposes, **chisels** are used. Among the chisels commonly used by the fitter are the cold chisel, the cape chisel, the round-nose chisel, the diamond-nose chisel, the floor chisel, the wood chisel, and the gouge. A *cold chisel* is shown in Fig. 40 (*a*); it is used chiefly for cutting cast-iron pipes, brick, stone, etc. A *half-round nose*, or *foal-foot*, *chisel*, as shown in Fig. 40 (*b*), is similar to the cape chisel, the chief difference being that the face of the chisel is ground to the outline of a colt's hoof; it is used chiefly for gouging, that is, cutting out a groove in heavy iron articles previous to cutting pieces off them with the cold chisel. A *cape chisel* is shown in Fig. 40 (*c*); it is similar to the cold chisel, but is narrower at the cutting edge, which is about $\frac{1}{4}$ inch wide; it is used for cutting iron, brick, stone, etc. A *diamond-nose chisel*, as shown in Fig. 40 (*d*), is similar to the foal-foot chisel, except that the nose is ground to the form of a diamond; it is used for the same purpose as the foal-foot chisel. A *floor chisel* is shown in Fig. 40 (*e*); it is simply a cold chisel with a very wide, thin face; it is used for driving into floor joints, cutting the tongue, and raising the boards without otherwise injuring the wood. The *wood chisel* may be provided with a wooden handle, or it may

be made out of bar steel, as in Fig. 40 (*f*), the latter being preferable. A *gouge* is similar to a common wood chisel, but curved at the cutting end, as in Fig. 40 (*g*); it is used chiefly

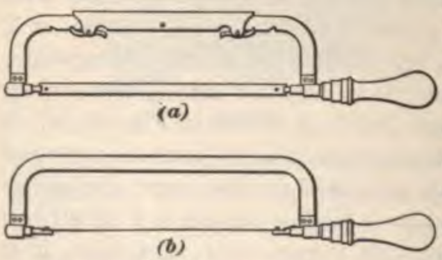


(*a*) (*b*) (*c*) (*d*) (*e*) (*f*) (*g*)

FIG. 40

for cutting recesses, often called *roads*, for pipes. Brick chisels are usually much longer than cold chisels, because they are used to cut holes through brick walls, which are generally quite thick.

43. The **hack saw** is a handy tool for cutting pipes, rods, and in fact, all kinds of metallic bodies. It consists of a hand frame, some forms of which are adjustable, as in Fig. 41 (*a*), in which is held a narrow saw blade that is tightened to any desired degree of tension by screwing up the frame handle. The saw blades are made in lengths of from 6 to 16 inches, and even longer, and the clamps by which they are held in the frame are so arranged that they may be



(*a*)

(*b*)

FIG. 41

set in four positions, in order that the saw may be operated in any direction. Fig. 41 (*b*) shows the saw blade set in a non-adjustable hand frame at right angles to the plane of the frame, the latter being to the right of the blade. It will be understood, of course, that where the conditions demand it the same position of the blade may be secured with the frame at the left of the blade. Hack-saw blades are so hard that they cannot be filed, and so cheap that when dull they may be thrown away. For sawing pipe they are made with about 25 teeth per inch, are about $\frac{1}{40}$ inch thick, and $\frac{1}{2}$ inch wide. The 8- and 10-inch blades are the most economical to use, the longer being more liable to become cramped and broken.

The fitter has occasion to use two types of **wood saw**, viz., the *cross-cut* and *compass saws*. The former is employed in the cross, or straight, cutting of flooring or beams, while the latter is necessary in cutting circular-shaped or other openings for piping. The compass saw has a handle like that of the common cross-cut saw, but the blade is very narrow, so that curved or other cuts may be made in any direction. It is especially useful in cutting holes in floors, etc. that are too large to be cut by an extension bit.

44. Measuring and Testing Tools.—Satisfactory results cannot be secured unless careful measurements for the work to be done are taken, and while the 2-foot rule is very useful, longer distances than are easily measured by it should be determined by using a **tape line**, which method is more accurate. Steel tape lines are the most accurate but the rough usage and the difficulties under which the tape has to be used by fitters makes the steel tape unsuitable, and therefore the heavy linen water-proof tape, in leather case, is most commonly used.

45. The **steel square** commonly used by carpenters should find a place in the fitter's tool kit, for in connection with the tape, the square is required to get the measure of angles.

46. In order to get the proper grade to the piping and to determine whether the apparatus set up is level, a **spirit**

level, such as that shown in Fig. 42, is used. The leveling glass *a* is used in testing horizontal lines and surfaces. The glass *b*, placed at right angles to the horizontal, is used in testing vertical surfaces. The essential feature of a level is the glass tube or vial, which is nearly filled with alcohol or ether and sealed at both ends. In the carpenter's level, the tube is slightly bent, as shown in Fig. 43 (*a*). It is obvious that the air contained in the tube will always seek the

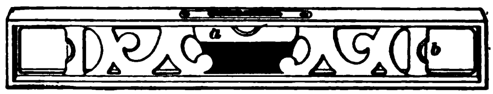


FIG. 42

highest point. Owing to this fact, the tube is mounted with its high side up. A line is generally scratched on the glass at *a*, or a line may be scratched at each side of the bubble, so that when the level is set on a level surface, the bubble stands central with the marks. For work requiring the greatest accuracy, the ground-glass tube is used. This is a tube ground on the inside to a barrel shape, as shown somewhat exaggerated in Fig. 43 (*b*). The curve in these glasses

FIG. 43

is very slight, being from 25 to 50 feet or more in radius. The less curve there is in the glass, the more sensitive will be the level. The bubble in the ground-glass tube is much longer than that in the bent one. The carpenter's level is generally made of hardwood, the best of them being built up of several hard, well-seasoned strips glued together. The level shown in Fig. 42 has an iron frame. Those in common use by pipe fitters have tubes like that shown in Fig. 43 (*a*).

47. For the purpose of determining whether upright pipes are strictly vertical, or *plumb*, the pipe fitter uses a **plumb-bob**, of which several forms are shown in Fig. 44.

The **plumb-bob** consists of a weight hung by a string or wire. For some purposes, a nut tied to the end of a string is sometimes used, but for neat work a special form of weight is employed. A form that takes little space and has many advantages is shown in Fig. 44 (*a*). This is made by drilling out a steel rod *a* and filling the space *b* with mercury, which is held in place by the screw *c*. The cap *d* has a small hole through it, which is counterbored in the bottom to hold the knot in the line, which should be braided or woven. The small diameter of this tool makes it particularly useful when hung near an upright partition, or in

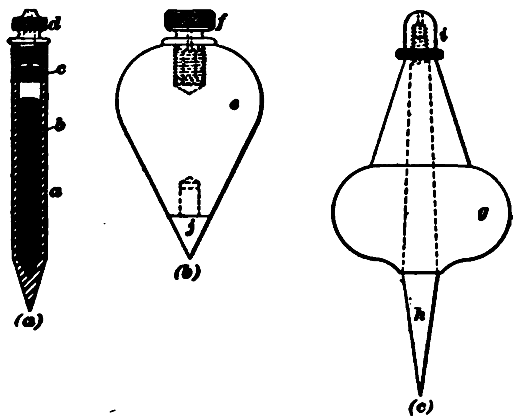


FIG. 44

windy places. The point is ground true. The most common form of plumb-bob is that shown in Fig. 44 (*b*); it is often made with a brass body *e* having an inserted steel point *j* and the usual cap *f* for holding the line. This plumb-bob has most of its weight at the upper end, which makes it somewhat unsteady. A better form, for use where great accuracy is desired, is that shown in Fig. 44 (*c*). This is made with a brass body *g* having its greatest weight at the lower end to insure steadiness. The point *h* fits the taper hole through the body *g* and is held in position by the cap *i*. The point is readily removed for repairs and may be used without the body by simply screwing on the cap.

In using a plumb-bob, if the line is unusually long, so that there is a tendency to vibrate, the plumb-bob is sometimes allowed to hang in a pail of water or oil in order to steady it.

48. Miscellaneous Small Tools.—In using chisels, a good **hammer**, heavy enough to break a fitting and to strike a powerful blow, is required. It should have a flat face at one end, and a rounded face at the other end for use in beating metal to a curve, or to bend it locally. Accordingly, what is known as the *ball-peen hammer*, shown in Fig. 45 (*a*), is the most suitable for pipe fitters' use. It weighs from 1 to $1\frac{3}{4}$ pounds and is used for all ordinary work, including riveting. The handle is from 14 to 15 inches long and of

FIG. 45

such size as to fit the hand comfortably; a handle that does not fit the hand well is apt to tire or cramp the hand when used continuously for a long time. Near the hammer head the handle is made a little thinner, as shown at *a*, Fig. 45 (*a*), to make it springy and thus obviate stinging the hand when a blow is struck. The peen of the hammer is used in riveting, or where it is required to stretch a piece of metal in width and length, or for working in a hollow. *Cross-peen* and *straight-peen* hammers, illustrated in Fig. 45 (*b*) and (*c*), respectively, are to be found in the large fitters' shops, where the former is used for riveting and also for stretching metal lengthwise, but not crosswise, while the straight-peen hammer is used for stretching the metal crosswise or sidewise.

49. The **center punch** shown in Fig. 46 is used for punching the centers of holes to be drilled, so as to start the drill properly. Among other uses, the center punch is also employed for marking flanges so that the two marked points

FIG. 46

will match properly when the flanges are put together after having been separated. Center punches should be ground to an angle of 60°.

50. The **trowel** used by bricklayers is needed by the pipe fitter for patching up places where the plaster work has been broken, to fill up holes through which pipes pass and for similar work.

51. A **screwdriver** is a very useful tool for a pipe fitter; its form and use being very well known, no description is deemed necessary. It is advisable to have several sizes of screwdrivers in the pipe fitter's tool chest in order to be able to select one suitable for the work to be performed.

52. The pipe fitter's outfit should embrace a **squirt oil can** of malleable iron, as the hard knocks it is bound to receive would soon destroy the ordinary sheet-zinc oil can. Oil is necessary in reducing friction when threads are being cut, in cleaning dirt out of threads, in loosening joints, etc.

53. Supplies.—Starting with clean tools and clean pipe fittings, they should be kept clean, to get good work, by using the best cotton waste, which is put up in bales and is the refuse from the spindles of the cotton mill. There are different grades of waste, from white to the mixture that comes from the clippings of prints, but only the best grade should be used.

The best material to use in making up joints is plain boiled linseed oil, there being no grit in it; the pipe screws up practically iron to iron, while the oil lubricates the thread and permits the fittings to be screwed up easily. Pigments have

been used for so long a time, however, that indifferent workmen want a pipe cement to make poor joints stay tight. Mixtures of white lead, red lead, oxide of iron, yellow earth, and other pigments are therefore mixed with oil and sold as pipe cement. Next to making up the joint iron to iron with oil, red lead and graphite paints are the best substances in common use for making up screw joints.

PIPE-HOLDING DEVICES

54. Pipe Vises.—For holding pipe rigid, either while it is being cut or while being threaded, or for screwing on fittings, a **pipe vise** is used. A commonly used pipe vise, known as the *Armstrong pipe vise*, is shown in Fig. 47. Two hardened-steel jaws, a, a', having teeth, are made to grip the outer surface of a pipe placed between them by turning the handle and thus operating the screw. The vise is secured to a work bench or some other solid support by means of either lagscrews or bolts and nuts. In the figure, the vise is shown open, that is, the upper frame b is swung up around the center c, which forms a hinge. When it is to be used, b is swung down and is secured by the pin d. Pipe vises are made of malleable iron or of steel castings. The teeth of both the pipe vises and pipe wrenches should be kept sharp, since if they become dull, they will slip and cut

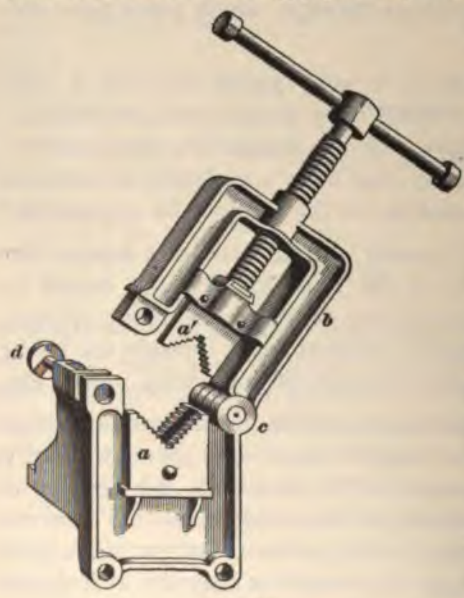


FIG. 47

a furrow around the pipe, and thereby weaken it; besides, such marring of the pipe conveys the impression of bad workmanship.

The *combination pipe and bench vise*, shown in Fig. 48, is a type of vise designed to be secured to the bench wherever convenient to hold the pipe, so that threads can be cut or fittings screwed on the pipe when clamped fast, the jaws *a*, *a* biting into the pipe so that it will not turn. The combination vise may also be used as a machinist's vise, and for work other than holding pipe; for instance, valves can be placed between the parallel jaws without damaging them. It is easily transported, being comparatively light in weight.

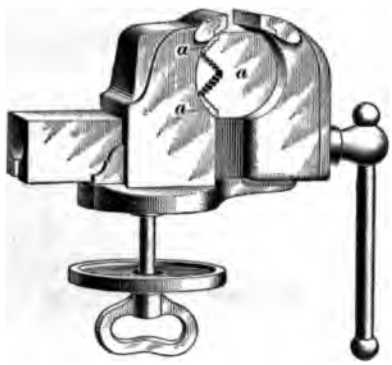


FIG. 48

55. Nipple Chucks. When it is necessary to thread a piece of pipe that is too short to be held in the vise, a **nipple chuck**, also called a **nipple holder**, is used. Frequently this is simply a pipe coupling *a*, Fig. 49, screwed over the end of a piece of pipe *b*, long enough to be held in the vise. The short piece, or nipple *c*, which has been threaded on one end before cutting it off the pipe, should be screwed into the coupling until it butts against the end of the pipe *b*, as this prevents swelling and splitting of the coupling. After a long nipple has been cut, it can be unscrewed with a pipe wrench; to remove a close nipple from the nipple chuck, the coupling *a* should be unscrewed a little from the piece *b* held in the pipe vise, when the nipple can be screwed out with the fingers. When close nipples are to be cut, the threaded end should enter the coupling a little

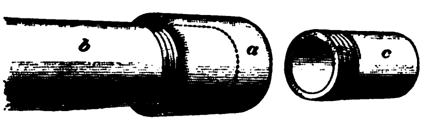


FIG. 49

less than the length of the perfect threads, and then butt against the piece held in the vise.

Fig. 50 shows a very convenient form of nipple holder for threading short and close nipples. In order that it may withstand rough usage, it is made of tool steel. When in use, the shank *a* is gripped firmly in the vise, and the nipple *b* to be threaded is screwed with the fingers into the collar *c*, as shown. The wedge *d* is then driven in lightly, so that the plunger *e* is held firmly against the nipple. The collar *c* acts as a guide for the die stock while the dies cut a thread on the part *b*. To remove the nipple, it is only necessary to drive back the wedge, which releases the plunger, allowing the nipple to be removed by hand.

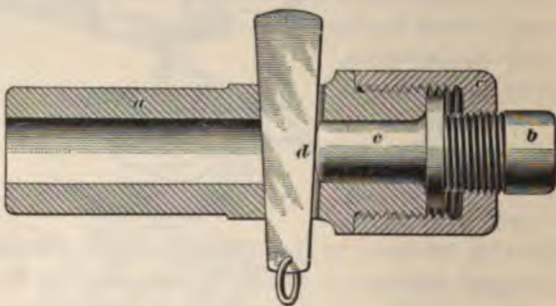


FIG. 50

56. Pipe Fitters' Bench.—A first-class **bench** for the use of pipe fitters is made as shown in Fig. 51. It usually has a top *a* made of a wooden plank about 18 or 20 inches wide by 5 or 6 feet long and 2 inches thick, to which are attached legs *b*, *b* made of $1\frac{1}{2}$-inch pipe. The legs have flanges at the top and bottom, which may be secured with lagscrews to the bench top and floor, respectively. The pipe vise is placed at one end of the bench, as shown, and is usually secured thereto by bolts passing through the plank, and by lagscrews at the end of the bench. The locknuts *c* are placed on the long threaded ends of the braces *e*, which are screwed tightly into T's *d*, the locknuts being run back on the thread and jammed up tight to make a rigid joint. In

order to prevent oil from soiling the flooring, finished floors should be protected by building paper or rubber cloth, but to rough flooring the flanges supporting the bench can be fastened by lagscrews.

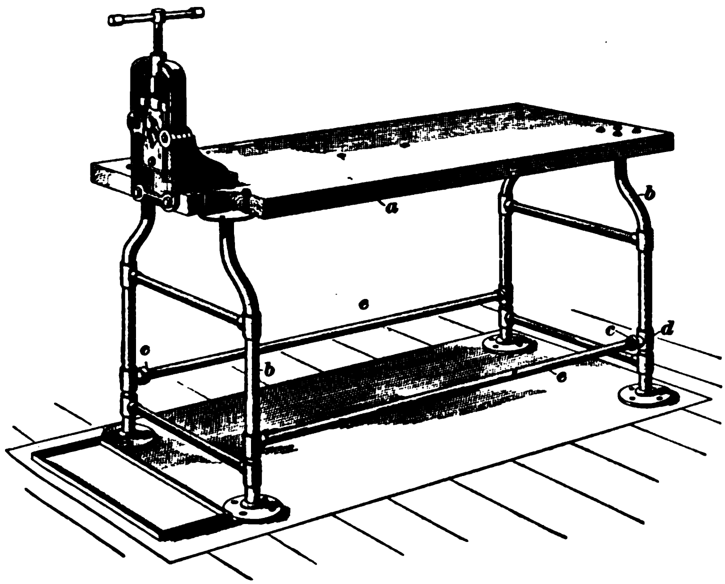


Fig. 51

PIPE FITTERS' TOOL OUTFIT

57. A summary of the tools embraced in the complete equipment with which the fitter should be provided to undertake practical work is presented in the following list. When a stock of tools is shipped to a job, a list similar to the one given here should be kept in the office, the tools that are shipped being charged against the foreman on the job. This list should be canceled when all the itemized tools are returned or accounted for.

LIST OF TOOLS

NAMES OF TOOLS	NUMBER OF TOOLS
Bench, 20′ × 6′ 0′′	1
Tool chest	1
Vise	1
Common tongs, 2-inch	2
Common tongs, $1\frac{1}{2}$-inch	2
Common tongs, $1\frac{1}{4}$-inch	2
Common tongs, 1-inch	2
Common tongs, $\frac{3}{4}$-inch	2
Common tongs, $\frac{1}{2}$-inch	2
Common tongs, $\frac{3}{8}$-inch	2
Common tongs, $\frac{1}{4}$-inch	2
No. 2 chain tongs (Robbins', or equivalent)	1
No. 4 chain tongs (Robbins', or equivalent)	1
No. 4 adjustable tongs (Brown's, or equivalent)	1
No. 1 Saunders cutter	1
No. 2 Saunders cutter	1
No. 2 Armstrong stock and dies, right and left, $\frac{1}{4}$-inch to 1-inch, set	1
No. 3 Armstrong stock and dies, right and left, 1-inch to 2-inch, set	1
Pipe wrench, 18-inch	1
Pipe wrench, 24-inch	1
25-foot tape line	1
12-inch half-round file	1
12-inch flat file	1
10-inch round file	1
6-inch saw file	1
18-inch screwdriver	1
No. 8 tinners' shears	1
15-inch spirit level	1
Pocket level	1
12-inch flat pliers	1
Steel wood chisel	1
Steel gouge chisel	1
Cold chisel	1
Diamond chisel	1
Cape chisel	1
Round-nose chisel	1
12-inch brick chisel	1
24-inch brick chisel	1
Joint chisel	1
Steel floor chisel	1
No. 3 Climax or Lowell ratchet, or equivalent	1
Carpenters' bits, 4 16-inch to 16 16-inch, set	1
Augers, $\frac{1}{4}$-inch to 2-inch, set	1
Plumb-bob and line	1
$8\frac{1}{2}$-inch bricklayer's trowel	1
2-pound machinist hammer	1
Center punch	1
Monkeywrench, 6-inch	1
Monkeywrench, 12-inch	1
Monkeywrench, 18-inch	1
12-inch ratchet brace	1
20-inch hand saw	1
12-inch compass saw	1
18-inch steel square	1
Extension bit, 2 blades	1
10-inch ratchet wrench	1
24-inch search gimlet	1
4-inch small gimlet	1
No. 2 Beatty's $\frac{1}{2}$ hatchet, or its equivalent	1
Taps, $\frac{1}{8}$-inch to 2-inch, right and left, set	1
Drills, $\frac{1}{8}$-inch to 2-inch, set	1
No. 2 malleable-iron oil can	1
Lead pot and brush	1
5 pounds waste, white lead, oil for cutting.	

SHOP TOOLS AND EQUIPMENT

PIPE-THREADING AND CUTTING MACHINES

58. As the threading of large pipes requires the exertion of more force than can be directly applied to the ordinary types of small hand tools, such work is done by specially designed hand- or power-driven machines, many of

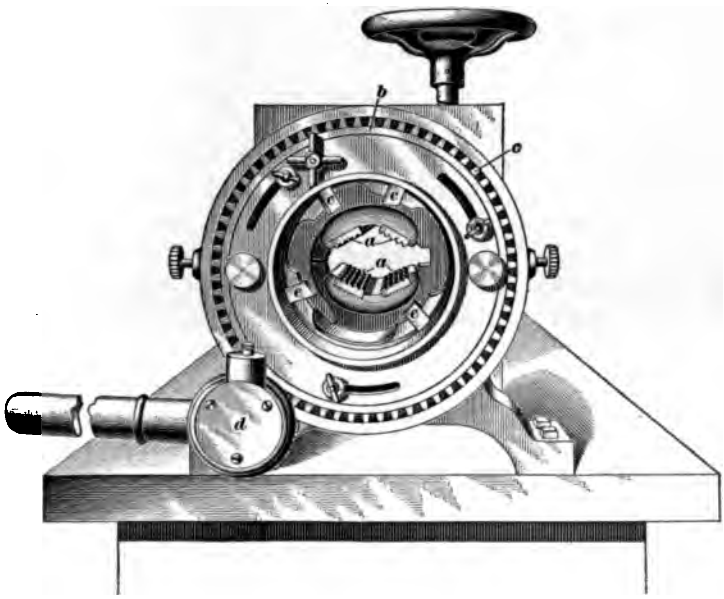


FIG. 52

which resemble lathes in general outline. The force transmitted through the handle of the crank of hand-driven threading machines is multiplied by gear-wheels; hence, the speed of the dies is correspondingly decreased, and the work of threading large sizes of pipe is thereby made comparatively easy.

59. A Forbes bench machine for threading and cutting pipe up to 6 inches in diameter by hand is shown in Fig. 52. It is provided with a vise at the rear whose jaws *a*, *a*, by a

parallel motion, are made to grip the pipe and hold it while the die-carrying plate *b* is revolved around it; on the outer rim, the die plate has gear-teeth *c* that are engaged by the teeth of a pinion journaled to the base of the machine at *d*, the pinion being operated by a ratchet and pawl on the pinion shaft. The dies *e*, *e* are placed in a framework that can be adjusted to fit the various sizes of pipe that are to be threaded or cut. Machines of this and larger types are made to be operated by motors or belting, as well as by hand, for shop work.

60. The Jarecki pipe-threading and cutting-off machine, illustrated in Fig. 53, is driven by hand, a crank-handle *a* being attached to the flywheel *b*, the force being transmitted by bevel and other gearing. The pipe to be threaded is put in at the rear, passing through the hollow spindle of the machine, the pipe being gripped and accurately centered at the extreme rear of the spindle by a universal, or self-centering, chuck operated by the hand wheel *c* and by a universal three-jaw chuck *d* at the front end of the hollow spindle, with which the pipe is thus made to revolve. The dies are mounted in a die head *e* and are adjusted to different sizes of pipe by means of a suitable cam, which forms a part of the mechanism of the die head, on which is also mounted a self-centering steady rest intended to steady the pipe while being cut by the cutting-off knife *f* in the knife stock *g* operated by the hand screw *h*. The die head is moved to and from the end of the threaded pipe by means of the hand wheel *i*, the die-head carriage sliding in the grooves *j*, *j*. After the pipe is threaded, the dies are expanded, or, in other words, drawn from the pipe, by the cam in the die head, and the die-head carriage is then run back by the hand wheel *i*. When the pipe is to be cut off, the dies are expanded far enough to readily permit the pipe to pass through them to the cutting-off knife *f*, for which oil is supplied from the tank *k* through the stop-cock *l*. For convenience in cutting a large number of threads of the same size without resetting the dies, an adjustable stop-pin *m* is

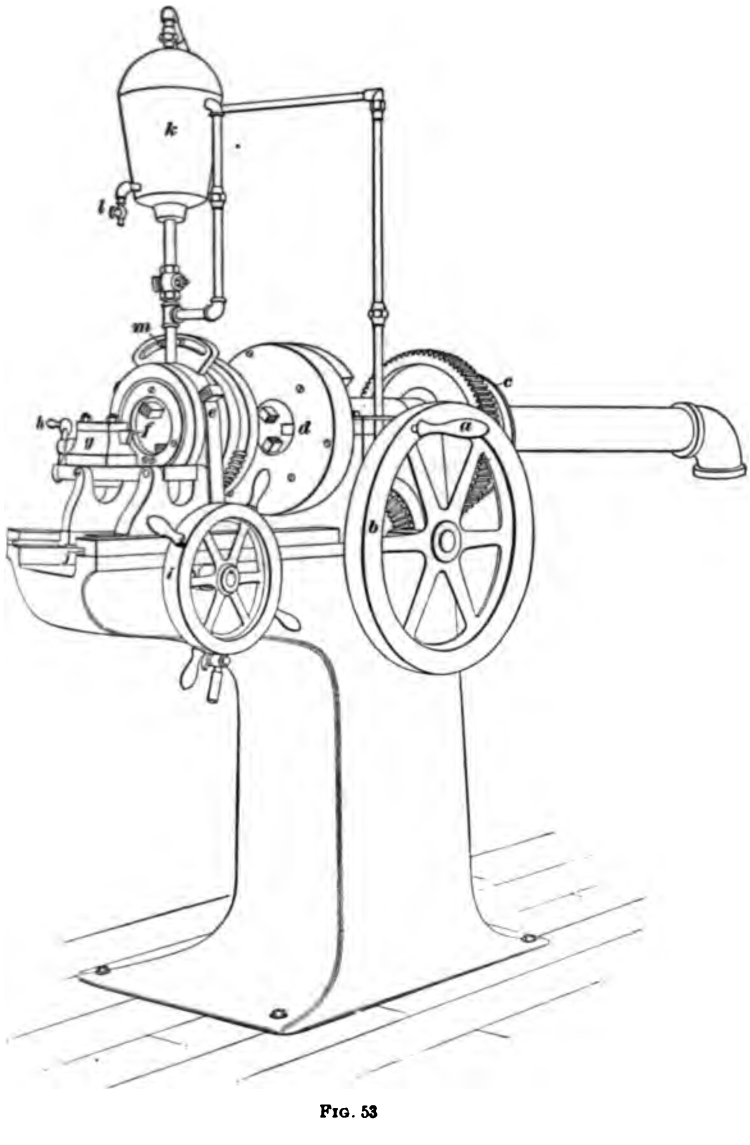


FIG. 53

provided, by which the movement of the die-adjusting cam may be limited, so that the dies may be returned to their proper position for cutting the required standard-size thread on the new piece of pipe after the threaded piece has been withdrawn.

EXAMPLE OF SHOP EQUIPMENT

61. The equipment and general layout of a well-arranged shop, such as is shown in plan and elevation in Fig. 54, and which is suitable for handling jobs of moderate size, will be here taken up in a general way, the character of the business done being assumed to be such as is common in cities of fairly large size, where there is considerable heating and power piping to do.

The private office should be a bright, cheerful place facing the street. In this room should be a roll-top desk *a*, catalog case *b*, drafting table *c*, draftsman's cabinet *d*, and chairs. The partition should be glazed, the doors being located about as shown. The general office should have a bookkeeper's desk *e* with top shelves, a letter file *f*, superintendent's desk *g*, letter press *h*, and safe *i*. Beyond the office is located the tool room; this room should be fitted with shelving all around. These shelves may be about 18 inches in depth, and by the use of partitions placed from 12 to 18 inches apart bins are made at the sides of the room, the back bins being made larger. Some of the shelves at the back of the room may be left out to allow the long-handled tools to stand against the wall. Part of the shelf bins may be used for storing valves, and as these goods are expensive it is best to keep them locked up. Commencing at the right on entering the tool room, there are 40 bins, 5 bins in height, and 8 bins deep. The small tools can be placed on the top shelf and the heavy tools on the bottom, the other tools being distributed so as to be readily accessible. In the top bins may be placed such tools as files, chisels, saws, saw blades and handles, bits, augers, drills, reamers, screwdrivers, levels, etc.; on the next row dies, taps, ratchets, braces, and so on; with the tongs, according

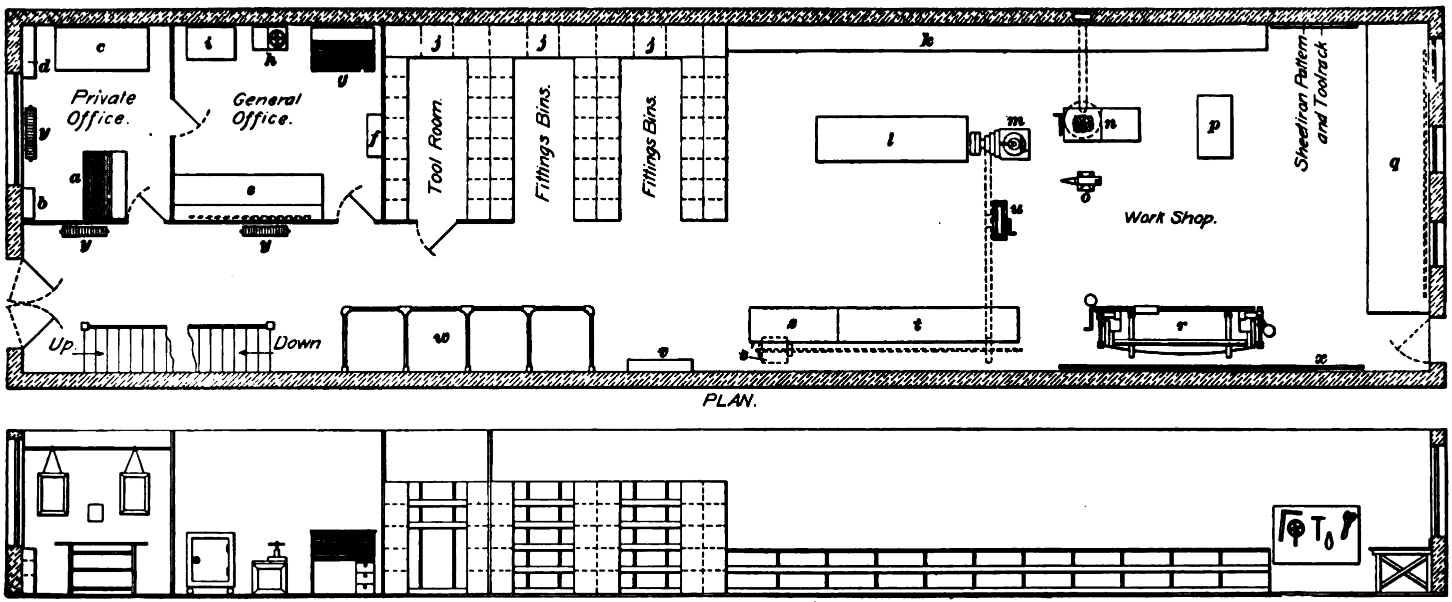

Private Office.
General Office.
Tool Room.
Fittings Bins.
Fittings Bins.
Work Shop.
Shediron Pattern and Toolrack
Up
Down
PLAN.
ELEVATION.

FIG. 54

to size, in the bottom bins. The chain tongs and other long tools may be placed at *j*, where the boxes may be omitted. The bins for fittings are built so that the space occupied will be as small as possible. In these bins the **L**'s can be arranged in the first row of bins at the bottom, then the right-and-left **L**'s, and then the reducing **L**'s, 45° **L**'s, etc. The next nest of bins may be for the nipples, placing the right-hand ones at the bottom, and above them the right-and-left, using separate bins for the long and the close nipples. The top row may be used for the right-and-left couplings, the large sizes being placed in the larger bins. The next nest of bins can be used for the **T**'s, placing the straight sizes at the bottom, and above them the **T**'s reducing on the run, then the branch-reducing, and above these the **Y** branches and the crosses, of which there is not so large a stock necessary as of the others. The last row can be used for miscellaneous fittings, hangers, etc. At *k* is a row of bins for branch **T**'s, coil hangers, tin tubes, floor and ceiling plates, and other things, together with wick packing, and other sundries that go to make up the stock that shops of this kind must keep on hand. These bins need not be as high as the fitting bins, but may be made with a counter shelf, as shown in the elevation. On this counter, the odds and ends may be stored in such a way that they are always in sight, to be used whenever possible; if stored in the cellar, they are out of sight, and, instead of being utilized, are liable to be kept needlessly on hand. The working portion of the shop is so placed that such odd jobs as building coils, drilling hangers, filing, and small blacksmithing for work in hand can be done as expeditiously and easily as possible. A small bench about 10 feet in length is located at *l*, and near it is a drill press *m*, forge *n*, and anvil *o*. At the rear of the workshop is located the sheet-iron department, with a punch and shear at *p*, work bench at *q*, and 8-foot brake at *r*. A threading and cutting-off machine, capable of cutting and threading pipe up to 8 inches in diameter, is located at *s*. At the rear of this machine is a bench *t*, which facilitates the handling of large pipe for cutting and threading, affording a support for

it. A stone for tool grinding is located at *u*. Over the pipe machine is fixed an electric motor *s'*, which may be used to run the drill press, as well as the pipe machine and grindstone, by means of a countershaft and pulleys. At one side of the pipe machine is a shelf and rack *v* for the dies and cutting tools, and about 15 feet forward of the machine is a pipe rack *w*, made of 1½-inch pipe, with railing fittings, to hold a stock of the pipe required for immediate use in the machine. The store and the offices should be warmed by hot water or steam radiators, coils being used in the rear of the shop. The coils are shown at *x*, and the radiators at *y*. The general office, being crowded with the desks and other office furniture, may be heated by placing a coil beneath the bookkeeper's desk, on the coldest partition.

62. The shop shown is such as might be installed in a building on an ordinary city lot, whose width is 25 feet and depth 100 feet. The building shown being 95 feet, there is a yard 5 feet deep at the rear for light and air. The building should have a dry cellar for the storage of scaffolding, heavy castings, tanks, boilers, general merchandise, and the general stock of pipe. There should be a sidewalk lift or hatchway to take in materials and get them out easily. The storage of materials should be made with judgment, passageways being left around the pipe and other materials for access thereto, and an unobstructed aisle should be left for taking goods in and out. Tags are required on each pile of material, and when articles are taken therefrom they should be checked off; in this way the shop will not become a storage place for the old junk and scrap, frequently found in many shops. The pipe and cast-iron scrap is best taken care of in bins set apart for it, and any short pipe that cannot be threaded in the machine, or made into nipples, should be sold for junk as soon as a ton of such pipe accumulates. Oil and waste should be placed in the front part of the cellar, where it is easy of access, and should be kept in sealed packages of iron or tin.

63. A list of all materials should be made on their arrival, whether they are received from the firm's warehouse, or returned from some job, a report being made to the bookkeeper, so that all materials may be credited by him to the proper accounts. All materials taken from the shelves should, if possible, be credited on the stock list of the respective bin or pile, a correct list thereof being given to the bookkeeper to charge to the job on which they are

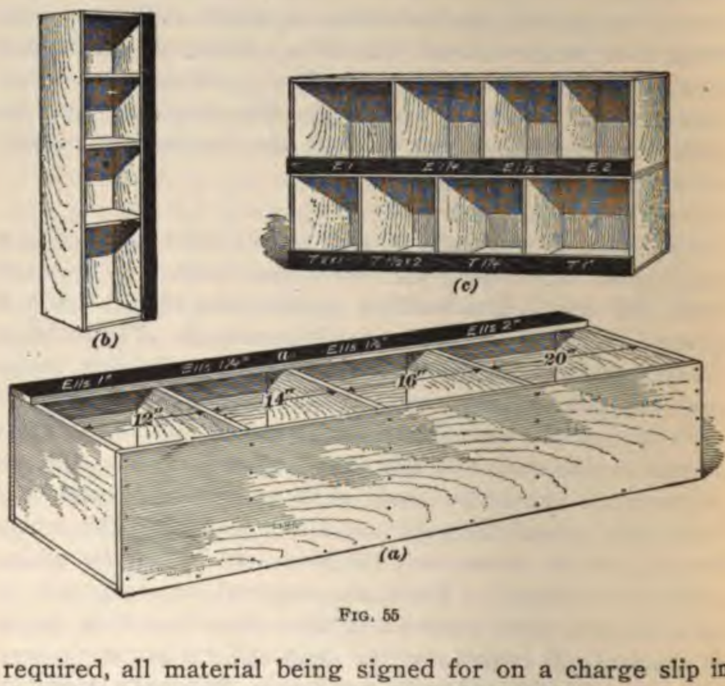


FIG. 55

required, all material being signed for on a charge slip in the office by the party taking such material. These methods should be strictly adhered to, as many goods, never used thereon, are often credited or changed by accident or otherwise to certain jobs; by means of the signed slip the responsibility therefore may be fixed. Tools should be kept locked up, the key being kept by the bookkeeper, to whom a check should be given by the party taking tools from the tool room. In this way the bookkeeper can follow up the

tools, and, having a receipt for the tool taken, can in case of loss charge the value of the tool to the loser.

Tools are often dulled and require sharpening; when returned from any job they should be sent to the machine department of the shop for inspection, sharpening, or other repairs, before they are placed in the tool room. Dull tools should be put in order at once, the time used in sharpening being charged to the tool account, and itemized under the head of maintenance account.

64. As a part of the shop equipment, several boxes should be provided for the assortment and transportation of fittings intended for use on jobs outside the shop. A good, easily transported box for small fittings that will serve for shipping fittings to the job, and for carrying back the left-over material, is shown in perspective in Fig. 55 (*a*). As the box is portable, it can be used for carrying an assortment of fittings for use on a floor away from the main stock. It is made of 1-inch boards, and the rim *a* permits the marking, which indicates the size of the fittings in their respective bins, to be seen at a glance. The box can be stood on edge, as at (*b*), or over a similar box, as at (*c*). The flat part *a* should be painted black, so that chalk marks can be made on it, showing the size of fittings in each compartment; this marking can be rubbed off when other fittings are placed in the bins.

PIPE-FITTING PRACTICE

(PART 1)

INSTALLATION OF PIPING

PIPEWORK DETAILS

INTRODUCTION

1. The practical work of the fitter being more or less trying and in many cases difficult, because of peculiar conditions that exist or may arise during the progress of work, it is advisable to keep a record of difficulties that have caused trouble and the manner in which they have been overcome, in order to be prepared by a careful analysis of these records to cope successfully and expeditiously with similar problems that otherwise would require a great amount of time and study for their successful solution.

Seemingly slight defects, such as a leak, discovered when steam is first turned on, sometimes necessitate taking down a line of pipe otherwise perfect in every detail. Such a leak may not be due to any fault in the character of the workmanship; it may be due to a sand hole in a fitting, to a split in the pipe so small as not to be seen until the pipe is subjected to steam pressure, to a crack in a **T** or similar fitting, to a broken section in a radiator, or to any other one or several of the many things that cause annoyance to the fitter. Some slight defects can easily be eliminated, while to remedy others is costly, and hence imperfections should be guarded against as much as possible. A sand hole in a fitting, if small, can be closed by peening the metal around the hole with the ball

end of a hammer; but if the hole is large, it should be drilled out and tapped, and a plug inserted. A split pipe should always be taken out and replaced with a sound one, although it may temporarily be stopped for preliminary testing by rusting it. To rust the split, a paste is made of fine iron filings mixed with a little sal ammoniac and water; this paste is plastered over the opening or split. The rapid oxidation or rusting of the filings causes the paste to adhere to the pipe, stopping up the crack.

In removing part of an old steam main that has been in service for a long time, as has to be done for instance for the purpose of connecting a new pipe to the main, it is generally a waste of time to attempt to unscrew the piping in order to save the fittings; in most cases it is cheaper to break with a heavy hammer the fittings nearest to the place where the new connection is to be made and to replace the broken fittings with new ones. The old pipe will be difficult to unscrew on account of the threads having rusted together with those of the fittings.

As much pitch as possible should be given to all pipes in order to insure proper drainage, by *pitch* being meant an inclination of the pipe from a horizontal position. Piping should be kept away from low doors and other passageways as much as possible, in order that the passage may be unobstructed. In putting up lines of piping, it is well to consider beforehand all the difficulties imposed by the construction of the building and other considerations, and how they may be removed or overcome. If this is not done beforehand, a long line of piping may have to be taken down and put up again in a different manner, thus entailing unnecessary expense and loss of time.

MAKING UP PIPES AND FITTINGS

2. Making Up Screw Threads.—Many specifications for piping jobs call for pipes to be screwed into their respective fittings without the use of any cement on the screw threads. The tightness of the screw joint then depends on

the perfect fit of the threads and their metal-to-metal contact. The act of joining pipes and fittings by screwing them together is usually spoken of by pipe fitters as **making up.**

To avoid slight leaks, it is customary for pipe fitters to use cement on the threads when the specifications do not prohibit its use. While a good cement, such as red lead and boiled linseed oil, or graphite paint, is valuable, not only in preventing leaks but also as a lubricant, there is a liability of careless mechanics using so much cement in the threads of the fittings that a quantity is forced inside the pipe. This may break away from the pipe and be carried through the system by the water of condensation or steam and stick in the valve seats, thus giving trouble; or the cement may be of such a mixture as to produce disagreeable odors in the steam that escapes from the air vents. The proper way to apply cement to the joints is to paint the first three or four threads of the fitting very thinly and to paint the entire male thread; then, should there be a surplus of cement, it will be squeezed to the outside and not inside. After making up a joint with cement, the pipe fitter should always wipe off the surplus cement to give clean-looking work.

3. Making Up Pipe Fittings.—Whenever it can be done advantageously, time may be saved by making up pipes and fittings at the bench, where the pipe can be firmly held in the vise. For example, **T**'s and **L**'s may be screwed on the ends of pipe so far as possible by hand. Then a short piece of pipe, which serves as a lever handle, may be screwed by hand into the side outlet or opening of the fitting, which may then be easily revolved on the pipe until it is tightly screwed up. The short piece of pipe serving as a lever handle is then unscrewed. If no piece of pipe is available for use as a lever handle, a Stillson wrench may be applied to the fitting.

4. In making up, that is, screwing on, valves made of brass, the pipe fitter should use the monkeywrench, applying it to the hexagonal shoulder of the valve at the end into which the pipe is being screwed. He should not apply the wrench to the other end, as by so doing he may deform the

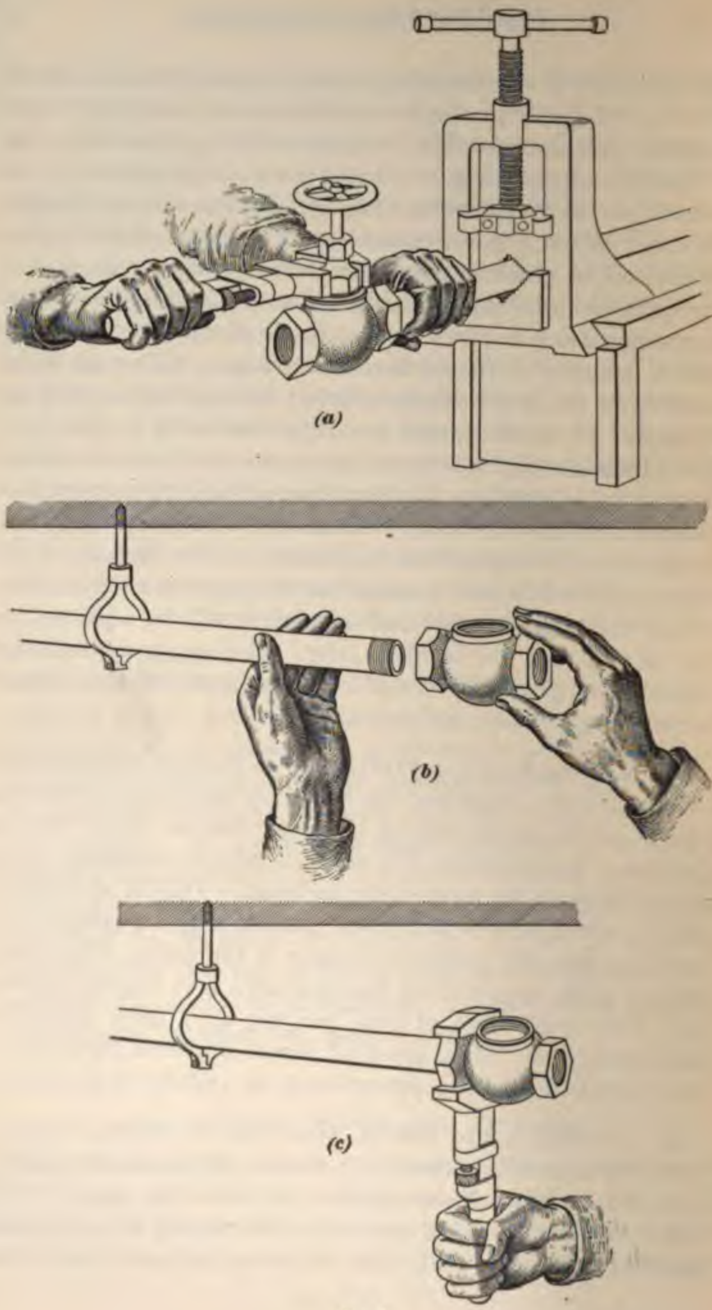


FIG. 1

valve body. A Stillson wrench or pipe tongs should never be used on brass or nickel-plated brass valves, because they cut into the metal and plating and thus mar the appearance of the valves. Valves are usually screwed on pipes with the stems and bonnets left on, but there are many places where valves must be installed close to walls or beams, and it is then necessary to unscrew the bonnets. For instance, a 2-inch pipe hangs 3 or 4 inches from the ceiling and a valve is to be screwed on the end of the pipe, which cannot be drawn down far enough for the valve handle to clear the ceiling while the valve is being screwed on. A short piece of 2-inch pipe is held in the vise, as in Fig. 1 (*a*), the valve screwed on the pipe, and a monkeywrench then applied to the shoulder on the bonnet, as shown, and the bonnet is removed. The valve body is next removed from the piece of pipe held in the vise and placed

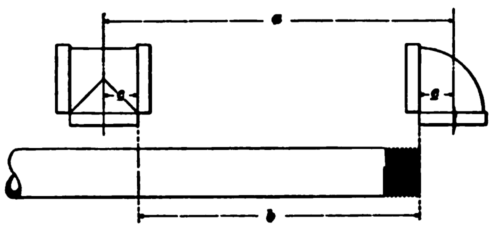


FIG. 2

on the end of the pipe at the ceiling, as shown in Fig. 1 (*b*), and screwed on by hand as far as possible, a monkeywrench being used to screw the valve body up tight, as shown in Fig. 1 (*c*). The valve bonnet is then screwed on again.

5. Piping Measurements.—As in other lines of work, it is necessary to exercise care in taking and recording the various measurements for a piping job, in order that the different parts may assemble properly and with a minimum of waste.

6. When taking measurements for piping, the center-to-center distances of the different pipe lines are measured first, and then allowance is made for the fittings; that is, the distance *a*, Fig. 2, represents the center-to-center measurement, while the distance *b* represents the actual length to

which the connecting nipple or pipe should be cut, allowance being made for the distance *c* from the end of the thread to the center of each fitting.

Fig. 3 (*a*) shows a sample of pipework composed of four elbows, one **T**, two valves with wheel handles, and seven pieces of pipe. It is customary when a valve is placed in a pipe to consider the two pieces of pipe to which it is attached, together with the valve, as one piece; this accounts for the statement that there are seven pieces of pipe. The dimensions marked *a*, *b*, *c*, *d*, and *e* are measured and transferred

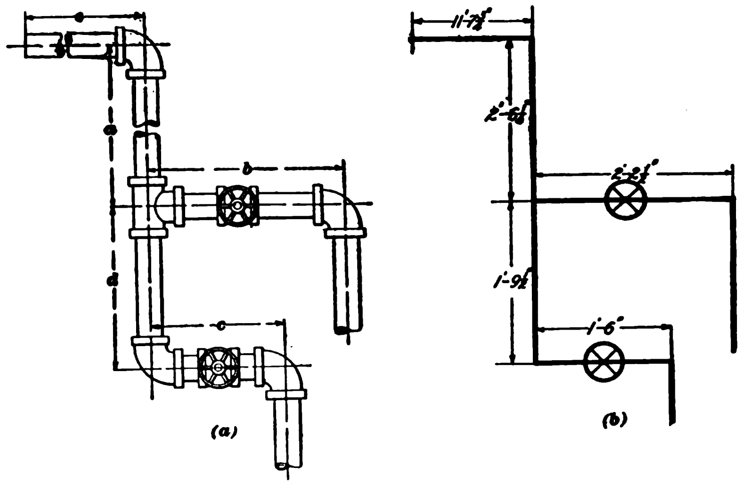


FIG. 3

for reference purposes to a sketch similar to that shown in Fig. 3 (*b*). It is customary in locating the valves to use a ready-made nipple on one side, and then to cut a piece for the other side sufficiently long to obtain the proper length of *b* or *c* when the whole is screwed up.

7. In measuring for 45° or 60° fittings, as where offsets are required, the pipe fitter must exercise considerable care. He may place the fittings in position and measure between them, using try pieces *a*, *a*, as shown in Fig. 4, that point straight toward each other, thus obtaining the measurement *b*, which will be the length of pipe required. In case,

however, that it is inconvenient to do this, the measurement *c*, representing the exact distance from center to center between the parallel pipe lines connected by the offset, may be taken, and the length of the diagonal line from center to center of 45° fittings is found by multiplying the distance *c* by 1.4142, and of 60° fittings by 1.1547. From the lengths thus found must be subtracted the distance between the ends of the diagonal pipe and the center of the fittings.

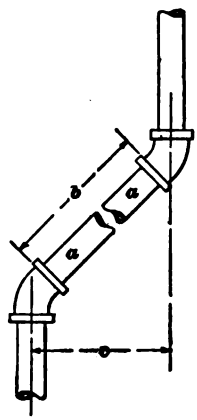


FIG. 4

EXAMPLE.—What length of pipe is required at *b*, Fig. 4, assuming that 1 inch is allowed between each end of the pipe and the center of each fitting, the distance *c* being 4 feet 9 inches, and 45° fittings being used?

SOLUTION.—Multiplying 4 ft. 9 in. = 57 in. by 1.4142 and subtracting the sum of the distances from the end of the pipe to the center of the fitting at each end, $57 \times 1.4142 - (1 + 1) = 78.6$ in., or a trifle over 6 ft. 6½ in. Ans.

8. A simple method for finding the diagonal length with 45° fittings is as follows: Strike two parallel chalk lines on the bench or floor to represent the center lines of the pipes to be joined by the diagonal piece, as *a b* and *c d*, Fig. 5.

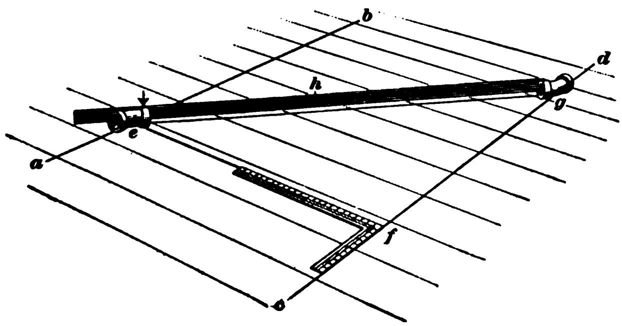


FIG. 5

Lay a steel square against one of these lines, as shown, and draw a perpendicular line *e f*. From the intersection at *f* on *c d*, lay off a point *g*, making *f g* equal to *e f*. Draw a line

through e and g. Then lay a 45° fitting over each of these intersections and measure with a rod h, as shown, the length of pipe required.

BENDING PIPE

9. Purpose.—There are three prime reasons why, for certain locations and uses, pipes should be bent. The first is to avoid, as much as possible, resistance to the flow of the fluids through the pipe; this applies particularly to pipes that convey steam to engines at a comparatively high velocity. The second is to avoid weakness due to angles, or abrupt changes, in the direction of the piping in places where it

FIG. 6

would be otherwise necessary to use fittings that may be broken by stresses due to expansion, contraction, or vibration; this applies also to engine and boiler connections, particularly on board ships. The third is to have the piping present a neat and workmanlike appearance; this applies to every first-class job. In addition, there is an economy due to the saving of fittings, and the saving of time wasted by waiting for them if they are not readily obtainable. It requires highly skilled workmen to make neat bends in pipes.

10. Cold Bending.—Pipes $1\frac{1}{2}$ inches or smaller are usually bent cold by the pipe fitter to fit their respective

positions. Pipes 1 inch and smaller may be bent cold by utilizing the holes that are commonly bored through the top of the fitter's bench. The larger sizes, however, which are liable to injure the top of the bench in bending them, may be bent by using a plank inclined at a suitable angle and properly braced, as shown in Fig. 6. A hole just large enough for the passage of the pipe is bored through the plank, and by pressing downwards on the pipe it may be curved, as shown, until given a bend of the required radius. Pipes up to $2\frac{1}{2}$ inches in diameter may

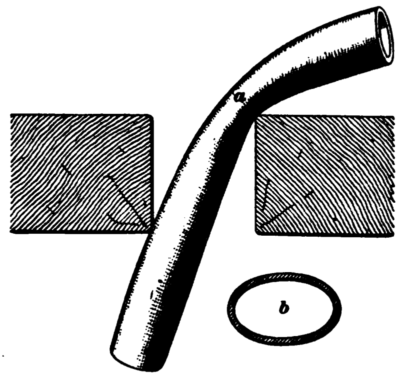


FIG. 7

be bent in this manner to a radius as small as ten times their diameter. Small pipes, if bent over a soft body, like wood, will not be kinked by the pressure on the edge of the wood, because their diameter is so small in comparison with the thickness of the metal that usually the bending is nearly uniform. Pipes of 2 inches diameter and larger, however, easily kink or become flattened at the bend during bending, as shown exaggerated at *a*, Fig. 7. A section through the bend is shown exaggerated at *b*. Imperfectly bent pipework of this description must never be put in a job. To avoid perceptibly flattening the larger sizes of pipe, it is necessary that the bending take place uniformly throughout a considerable length of the pipe. This can be done by bending the pipe a little at a time at different points by means of a plank. The bend shown in Fig. 8 illustrates how the pipe is then kinked in the bending process. The pipe is kinked a little at *a*, then pushed

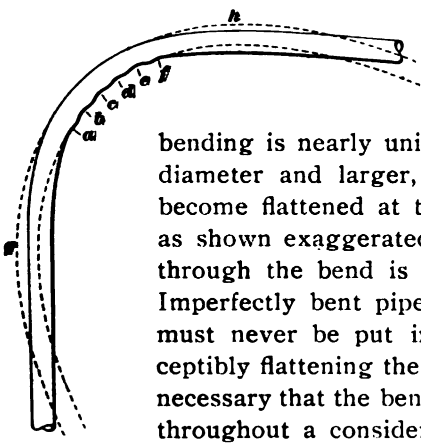


FIG. 8

through the hole a short distance, bent a little more and thus kinked at *b*, next being bent at *c*, *d*, *e*, and *f*, respectively, until the proper form is obtained. The kinks *a*, *b*, etc. are exaggerated in depth. A good mechanic can bend a pipe in this way without making the kinks deep enough to be noticeable to an ordinary observer. It frequently happens that the pipe must be bent more than actually required in order to get the correct curvature, as shown by the dotted lines in Fig. 8. This is due to the bending of the pipe between the plank and the hands. The pipe may be made straight by bending back at the points *g* and *h*.

In bending iron pipe, particular care should be taken to have the seam always at the inside curve. If it is located at the heel or at either side of the bend, it will be liable to split. It is least liable to damage at the center of the throat.

Pipe bending must be done slowly in order to obtain satisfactory results, the tension on the pipe being made such that the metal will yield evenly at the heel and compress smoothly at the throat; otherwise, the pipe will bulge out at the sides in the manner indicated at *b*, Fig. 7. Judicious hammering during the bending process will often preserve the shape of the pipe.

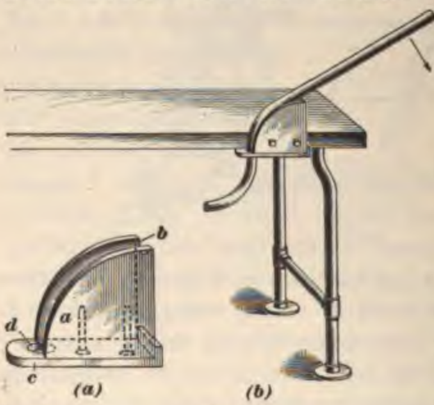


FIG. 9

11. Pipes may be bent in the groove of a curved **form**, the groove being made fully half the diameter of the pipe that is to be bent. This method of bending has the advantage of changing the bearing point of the pipe with every change made in the bend. Fig. 9 (*a*) shows a pipe-bending form, and Fig. 9 (*b*) its application. A wood block *a* provided with a suitable groove *b* is rigidly secured, by lagscrews, to an iron plate *c* having a hole *d* to fit the pipe

to be bent. This form may be secured to the side of the bench, as shown in Fig. 9 (*b*). The pipe is bent by pushing the short end into the hole *d* and pulling the long end over in the direction of the arrow. The form can be made of iron if desired. Good bends can be made by using forms.

12. The commonly used sizes of brass and copper pipes are bent cold; but in order to bend them properly, they must be first annealed, that is, it is necessary to heat them red hot at the places where they are to be bent, and then cool them in water. This softens the metal and makes it easy to bend the pipes cold in the ordinary forms; the small sizes can be bent without the use of forms. A form frequently used by fitters for bending brass and copper piping is shown in Fig. 10. A mark is made on the pipe *a* where the bend is to commence, and this mark is located at the strap *b*. The strap *c* is then slipped back to the notch in the block that will allow the base of the lever *d* to bear against the pipe. The lever is now pulled over until it can go no farther, and part of the bend is thus made.

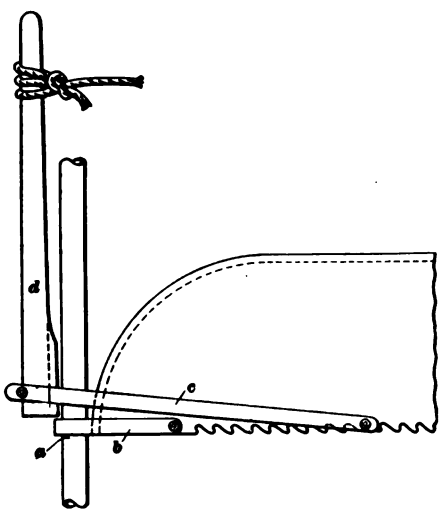


Fig. 10

The strap is then slipped a notch backwards, and another part of the bend is made. This process of nipping over a little at a time, as the step-by-step bending of the pipe is called, is continued until the short arm of the pipe is bent over to the desired angle. The base of the lever *d* is grooved to fit the pipe.

13. Hot Bending.—Large sizes of pipe require so great a force to bend them cold that they are always bent hot,

except when the bends required are slight. In the hot-bending process the pipe is heated, usually in a blacksmith's forge, to a bright red heat at the place where the bend is to be made. This makes the metal soft and allows it to be easily stretched or compressed.

14. Forms for hot bending must be made of iron, as the pipe bent over them is red hot. The method shown in Fig. 9 may be employed, or the form may, for convenience, be attached horizontally to the bench. With the form shown there is a liability of the pipe being flattened a little, as shown in Fig. 11 (*a*) by the tension on the metal of the outer curve, with a consequent spreading out of the sides. There is also a liability of the metal being stretched and made thinner at the outer curve, or **heel**, than at the inner curve, or **throat**, as shown in Fig. 11 (*b*). To avoid the spreading out of the sides of the bend, and consequently to obtain a neat bend, a roller and lever may be used in connection with the bending form. Fig. 12 shows how a pipe heated between the points *a* and *b* can be bent without spreading the sides. A cast-iron form *c* is bolted to the bench or other suitable block by bolts passing through the lugs *d*, *d*. A lever *e* is pivoted at the bolt *f*, which is the center of the arc of the form. A roller revolves on a pin *g*, and is located so that the space between the roller and the groove fits the pipe. The pipe is heated to the distance required to make the bend, and is pushed in between the form and roller to the proper point, usually indicated by chalk marks previously made on the pipe. One man then slowly pulls the long arm of the pipe around the form while the other man pushes the lever around in the same direction. Should the bending of the pipe spread it sidewise a little, the roller immediately brings it back into shape again. In

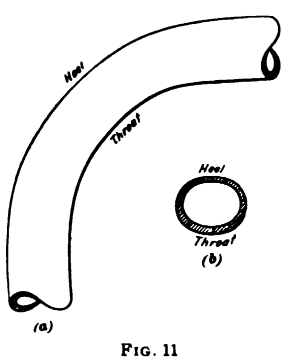


FIG. 11

this way good bends, practically circular in cross-section, are obtained after a little practice.

15. After pipe is heated to a bright red heat, it can be bent a little without being flattened. If the bent part is then gently held between the jaws of an ordinary bench vise, as shown in Fig. 13 (*a*) and (*b*), the bending may be continued without much danger of spreading. The pipe will naturally stretch and flatten at the heel and swell out sidewise under compression at the throat. In bending pipe without a form,

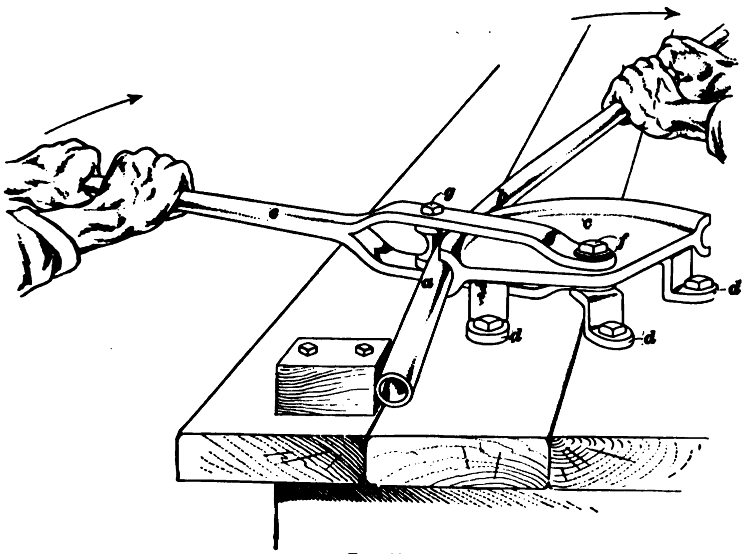


FIG. 12

it is frequently necessary to pour water on the part that has been sufficiently bent, in order to harden it at that point and thereby prevent further bending, which then takes place in the hot part of the pipe on either side of, or between, the cooled parts. When the correct curve is obtained in any part of the pipe, the remainder can be bent satisfactorily by using this chilling process, care being taken that the temperature of the metal throughout the portion to be bent is sufficiently uniform to insure a regular curve. Unless particular attention is paid to this feature of the process, some

parts will be bent more than others, as shown in Fig. 13 (*c*), in which the metal has been too hot at *a* and *b*. In making this bend, water should have been poured on at these points to cool the pipe slightly and thereby enable the pipe between them to be bent a little more. An experienced mechanic can make good bends by this method.

16. Large pipes that are too heavy to handle in the vise or in a form may be bent by hand at the forge, as shown in Fig. 14. The pipe *a*, we will assume, is 8 inches in diameter and 10 or 12 feet long. A short piece *b* is screwed on the end with a coupling *c* to give leverage in pulling that end over with blocks and tackle, as shown. A length of pipe is

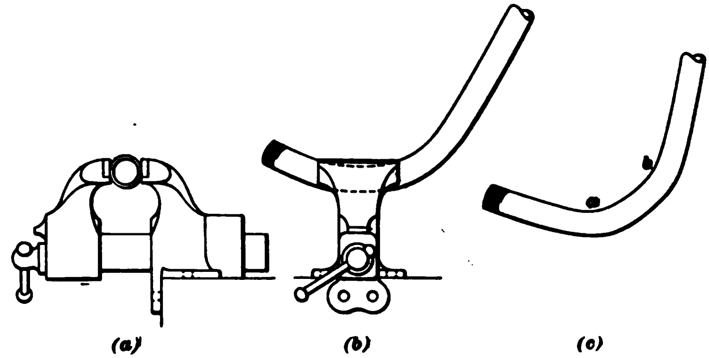


FIG. 13

screwed on the other end with a coupling *c'* to steady the pipe to be bent. The pipe *a* is heated at the forge, and when bright red it is pushed through the fire until beyond the forge. The mechanic in charge of the bending immediately clamps the pipe in position in supports at *e*, *e* attached to the wall, and places the clamp ring *f* close to the heated part to be bent, as shown, while his helper hooks on the tackle and pulls over the end *b*, the shape of the pipe being preserved by the use of the clamp and well-directed hammering on each side of it. The clamp ring *f* is a hinged ring having drift-pin holes in which a drift wedge is used to clamp the ring tightly around the pipe. The pipe is braced to keep it from moving when the pull comes on *b*, by the clamps at *e*, *e*, which

FIG. 14

fit loosely over the pipe. As the end *b* is pulled over, the pipe *a* bends at the heated spot, the tendency to flatten being prevented by the ring clamp and the judicious use of the hammer. The tendency to kink in the throat is overcome by pouring water on the pipe where the kink begins to appear, the spot yielding to compression being strengthened by the cooling of the water. The first part of the bend having been made, the clamp is removed and the pipe is pushed back a little at one side of, yet close to, the slight bend that has been made. When heated bright red, the pipe is pushed through the fire again and the bending process repeated, the arm *b* being pulled over still more. By repeated heating and bending, an accurate bend, with a true curve and a circular section at every point, can be made.

17. Use of Templets.—Pipes must frequently be bent to unusual curves in order to fit properly in their respective positions in a building. Small pipes may be bent so as to cover properly drawn chalk lines on the floor. This is the quickest way to get them into shape. Large pipes must, however, be made to fit a templet or pattern. This may be made by bending a piece of $\frac{3}{8}$-inch or $\frac{1}{2}$-inch pipe or rod to fit a drawing already laid out on the floor. The templet is then laid on top of the pipe that is being bent to see if the bends are being curved in accordance with the sketch. If the pipe is bent to fit the templet, no trouble should be encountered when the bend is put in place. If, however, the pipe is bent without regard to the requisite radius, or angle, as is liable to occur if no templet or an inaccurate one is used, it will probably have to be shipped back to the shop to be changed, and thus a great deal of labor and time may be lost.

18. Sketches for Bent Piping.—To make first-class bent pipework, it is necessary to have accurate working drawings of the bent pipes, the measurements being taken at the place where the piping is to be erected. The pipe fitter must first determine the exact location of the several pipe lines, and then make a separate sketch of each bend and offset required. He must also take care that the bends

when installed will appear neat and be in harmony with the interior architectural features of the structure.

19. Fig. 15 shows a sample working drawing, or sketch, of bends and offsets. All the dimensions necessary for making up this material by a man who has not seen the job

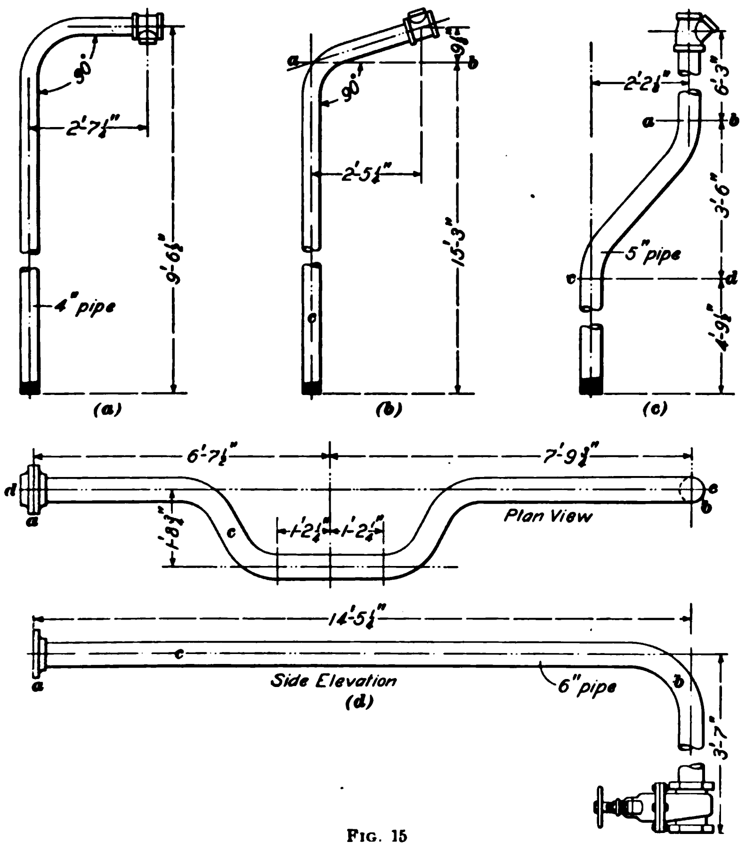


FIG. 15

are given. A common bend with a **T** screwed on one end is shown in Fig. 15 (*a*). The fitting is shown on the sketch because the measurement (2 feet 7¼ inches) between the center of the fitting and the center of the pipe is most essential. If the radius of the bend is not important, it is

customary to leave its size to the judgment of the man that bends the pipe.

The bend shown is a quarter, or 90°, bend. Should any other angle be desired, except 45°, it can be described as shown in Fig. 15 (*b*). The line *a b* is at right angles with the pipe *c*, and the angle of the bend is determined by the measurement given as $9\frac{1}{8}$ inches perpendicular to the line *a b* and from a point located 2 feet $5\frac{1}{4}$ inches to the right of the center line of *c*. If a 45° bend is desired, it is only necessary to state this, because 45° is an angle that can be laid off by drawing a right triangle having the sides adjacent to the right angle equal in length.

The dimensioning of an offset is shown in Fig. 15 (*c*). In this case, also, the radius of the curve of the bends is left to the judgment of the man that does the bending. If a curve of a particular radius or curvature is required, a templet or accurate drawing must be made. Bends of special shapes are expensive to make by hand because the available bending forms frequently do not suit.

The particular feature in Fig. 15 (*c*) is the location of the lines *a b* and *c d*, which precisely locate the position of the offset on the pipe. The pipe above *a b* and below *c d* is straight, the curves commencing at these lines. The most important measurement is the center to center dimension, 2 feet $2\frac{1}{8}$ inches.

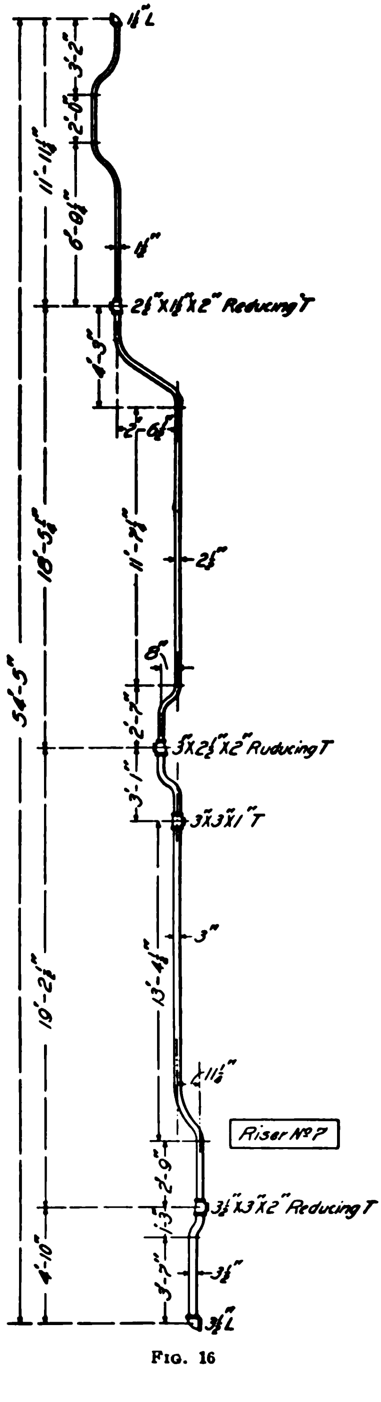
In Fig. 15 (*d*) is shown a length of a 6-inch pipe with a flange *a* screwed on one end, a bend *b* made on the other end, and a loop or double offset made at *c* to pass around the face of a square column. To take these measurements accurately, a plumb-line should be dropped over the center of the opening to which the drop pipe of the bend *b* is to be attached. Then, the 7 feet $9\frac{3}{4}$ inches dimension from the plumb-line to the center of the column, which is the center of the loop, is obtained and marked on the sketch. The 6 feet $7\frac{1}{2}$ inches dimension is next obtained and marked, and a cord is then stretched parallel with the main pipe line and measurements taken to see if the center of *b* is in line with the pipe on which the flange is to be attached. If it is in line, then the

center line de is drawn on the sketch. This means that the offset on one side of the loop should be a duplicate of that on the other side. If, however, the line de that represents a continuation of the main line, does not intersect the center of b, the sketch must show on which side is the center of b, and dimensions must accurately show the distance it is off the center.

20. A sketch for a riser is shown in Fig. 16. On heating plans, the pipe fitter should give each riser a number by which to identify it; thus, the illustration shows the bends required for riser No. 7. The bends should all be made in the shop, screwed together on the floor, checked up with the sketch, to be sure that no mistake has been made, and unscrewed again. All the pipes for this riser should then be tied together in one or more bundles and labeled "Riser No. 7." This is necessary to prevent confusion on the job should a big shipment of bent pipe come to hand at one time.

21. Some pipe fitters experience trouble with bent pipework because they do not make accurate sketches. If a sketch is wrong, and the pipes are bent to suit the sketch, the fault certainly lies with the pipe fitter, and the goods cannot be returned to the pipe-bending shop to be changed without payment for the required changes. If, however, the sketch is correct and the pipes are not bent or otherwise made up to suit the sketch, the pipe fitter need not accept them. Hence, the necessity of making accurate sketches is manifest. The pipe fitter on the job, or the foreman who is responsible for the accuracy of the sketch, should keep a duplicate copy.

In Fig. 16, the actual working, or detail, dimensions are given close to the pipes, and a little to the left the dimensions from center to center of certain fittings are given. When the pipes are assembled, these distances should be exactly as given on the sketch. It is necessary, therefore, that the bending of the smaller pieces be carefully done. Finally, the total length of the pipe line is given at the extreme left, in order that the accuracy of the work done on



$1\frac{1}{4}$" L
3'-2"
2'-0"
11'-11$\frac{1}{8}$"
6'-0$\frac{1}{8}$"
$1\frac{1}{4}$"
$2\frac{1}{2}$" X $1\frac{1}{4}$" X 2" Reducing T
4'-5"
2'-6$\frac{1}{4}$"
18'-5$\frac{1}{8}$"
11'-7$\frac{1}{8}$"
$2\frac{1}{2}$"
8"
54'-5"
2'-7"
3" X $2\frac{1}{2}$" X 2" Reducing T
3'-1"
3" X 3" X 1" T
3"
13'-4$\frac{1}{8}$"
19'-2$\frac{1}{8}$"
11$\frac{1}{2}$"
Riser No. 7
2'-9"
$3\frac{1}{2}$" X 3" X 2" Reducing T
1'-3"
4'-10"
3'-7"
$3\frac{1}{2}$"
$3\frac{1}{2}$" L

FIG. 16

the separate pieces may be determined by an overall measurement, and by this method of check-measurements, accurate work can readily be insured.

After the pipes are bent, screwed together, and checked up, the ends of the pieces that come together should be marked with different marks, so that there will be no excusable mistake in putting them together on the job. Thus, a **T** may be marked with a cross, and the end of each pipe that screws into that **T** should be marked with a similar cross. Another fitting may be marked with the letter *V*, the pipe ends that screw into it being similarly marked.

If any right-and-left couplings or flanges are required in the pipe line, their positions should be shown and dimensions given. The number actually required and their location will depend on the character of the work and whether the floors are laid or not. It is always advisable to install risers that have bends in their lengths, and have them tested, before the floors are laid.

ANCHORING AND SUPPORTING STEAM PIPES

22. Anchoring Risers.—Devices that serve to support risers and at the same time hold them rigidly at fixed points are known as **anchors.** That point of the riser where the support is attached remains stationary during expansion or contraction. The part above the riser support expands upwards; the part below the support expands downwards. The anchor in a riser usually supports the whole weight of the pipe line.

Risers and branches should be run in such a way that the movement of the piping, due to expansion, may take place freely in both directions from the point of support. Therefore, great care must be taken in the arrangement of the radiator connections to permit expansion of the riser without disturbing the radiators or their connections. The proper place to anchor a riser is at the middle of its length, since the maximum expansion in relation to the anchor is then but one-half of what it would be if the pipe were anchored at one of its ends.

23. Anchors may be made in various ways to meet the requirements. A few forms that will serve to suggest others are shown in Figs. 17 to 19. Fig. 17 shows a simple but satisfactory method of anchoring risers in ordinary residence work, where the risers are carried through three or four stories. It is made by inserting a piece of pipe *a* under the radiator branch and close to the riser, another pipe *b* being located on the other side of the riser to keep it in place. Holes are bored half way through the joist *c* to support the ends of *a* and *b*, and are bored entirely through

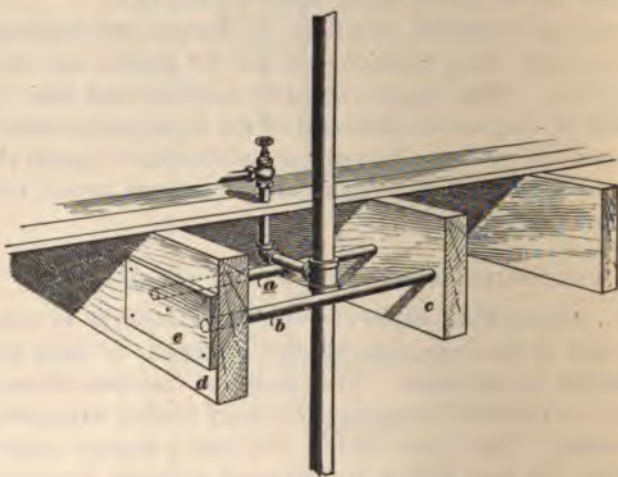


FIG. 17

the joist *d* to permit *a* and *b* to be inserted; a board *e* is nailed over these holes to hold the pipe in place.

Fig. 18 shows a few methods of anchoring especially adapted for use in high buildings of steel construction. The supports are made from iron forged into the shape required and clamped to the I beams to support the pipe. Fig. 18 (*a*) shows a clamp anchor bolted to the web of an I beam. The clamp embraces a nipple between two heavy beaded couplings in the riser, as shown. This prevents the riser from either rising or slipping down. In Fig. 18 (*b*) is shown a clamp that holds the riser against the flanges of an I beam,

the coupling being located above the clamp to prevent the riser from slipping down. Fig. 18 (*c*) shows a similar attachment with round hook bolts *a*, *a*, one end of which is hooked over the top flange; the other end is threaded to allow the clamp *b* to be drawn up tight by means of the nuts. Fig. 18 (*d*)

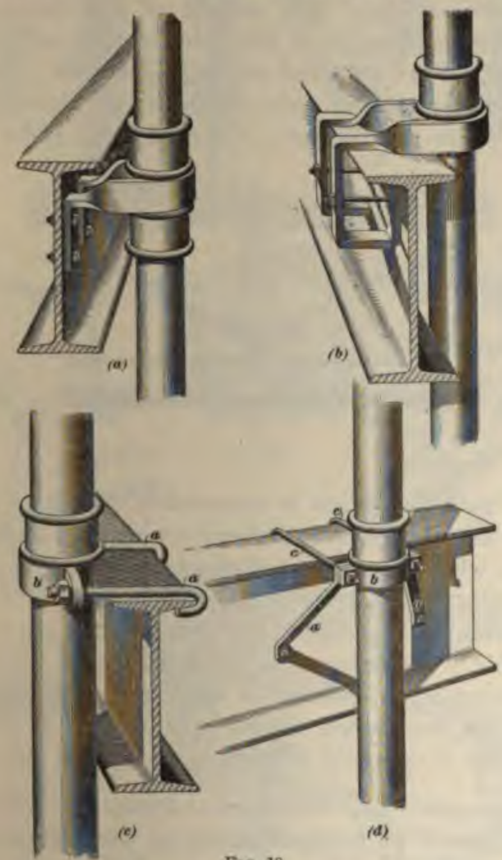


FIG. 18

shows a good anchor for a riser that is located a little distance from an **I** beam. The braces *a*, *a* are bolted to the web of the beam and carry the clamp *b* placed below the coupling shown. The top of the braces is confined laterally by the hook bolts *c*, *c*, hooked over the upper flange of the beam.

24. Anchoring Steam Mains.—Anchors on steam mains are especially constructed to hold immovably that part of the mains to which they are attached, in order that expansion may take place in both directions from the anchors. Fig. 19 shows an anchor attached to a wooden beam at the ceiling. The weight of the pipe is taken primarily by the hanger *a*; two tension rods provided with turnbuckles *b*, *b* are attached to the hanger and to the beam, and when these tension rods are drawn up tight a truss is formed. When the clamps *c*, *c* are clamped tightly to the

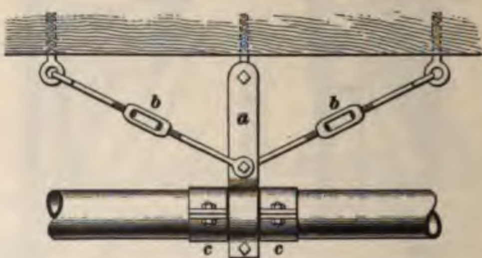


FIG. 19

main, this part of the line is immovable. Such an anchor is especially useful where high-speed engines are connected to the piping, when there is sometimes a great deal of vibration, and especially so if the pipe is not sufficiently large to provide an ample supply of steam to the engine when the throttle is opened wide. In such cases, when the steam supply to the cylinder is cut off at each stroke the impact of the steam jars the pipe, and the anchor shown is of service in preventing the vibration that would otherwise be caused thereby.

25. Special Pipe Hangers.—Pipes are usually supported by means of hangers placed at such distances from one another as to sustain safely the weight of the pipe, and at the same time withstand the effect of expansion and contraction stresses on the piping, as well as other stresses, such as the thrust of the branches and the expansion of riser pipes. The ordinary pipe hangers are good enough for the smaller sizes of pipe, where the stresses are also small, but

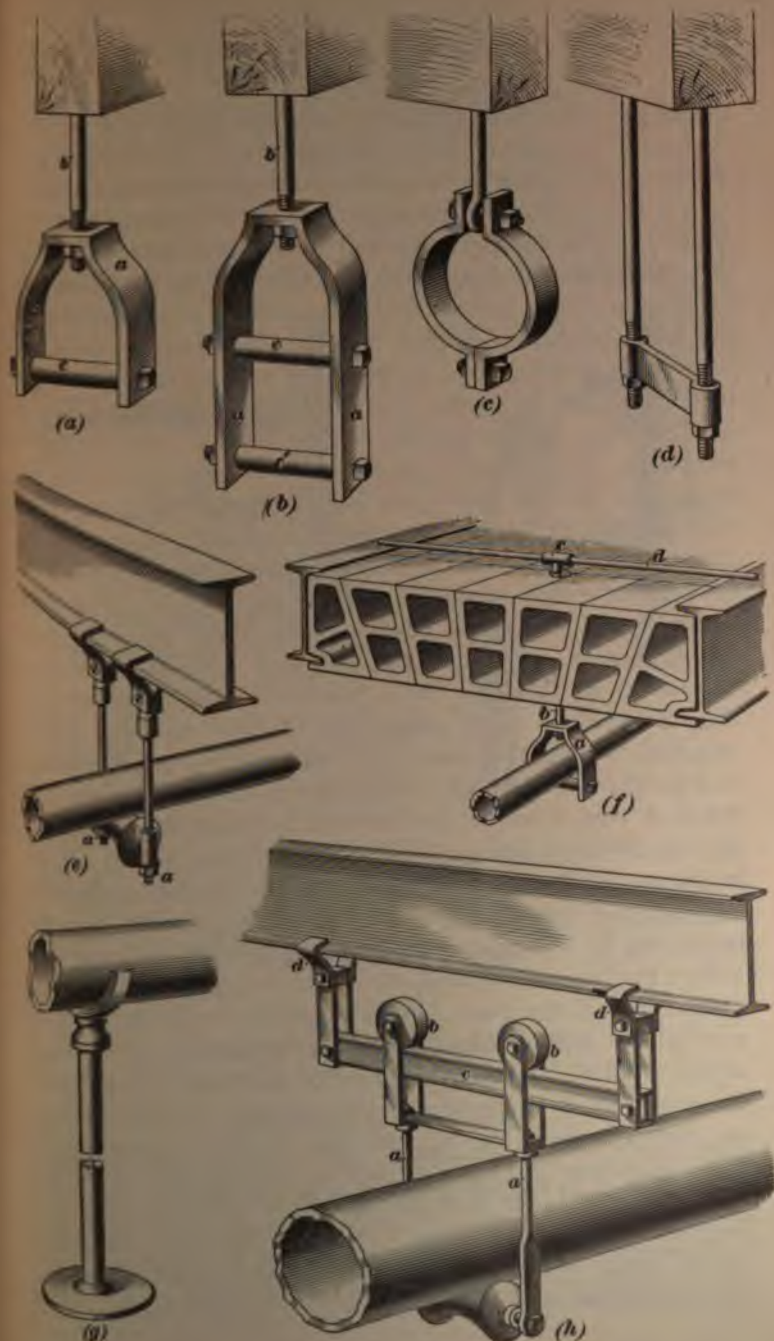


FIG. 20

for larger pipes it is frequently necessary to use especially designed hangers of heavy wrought iron, of which several patterns are shown in Fig. 20. A hanger having a yoke *a* with a hole at the top through which the hanging bolt *b* is slipped, and at the bottom a bolt with a pipe sleeve *c* serving as a roller for the pipe and thus preventing any sideward movement of the hanger during expansion or contraction of the pipe, is shown in Fig. 20 (*a*). The manner in which this type of hanger is utilized for supporting two pipes instead of one is shown in Fig. 20 (*b*). Another style of hanger often used is shown in Fig. 20 (*c*); this hanger is inferior to the one just shown, however, because the free expansion of the pipe line is interfered with, and also because the expansion subjects the hanger to a bending stress. A favorite hanger is shown in Fig. 20 (*d*); this form is somewhat expensive, and as the friction of the pipe resting on the cross-bar subjects it to a bending stress during expansion or contraction, and also interferes with free movement of the pipe, it is inferior to the one shown in Fig. 20 (*a*). A good roller pipe hanger intended to be attached to an I beam at right angles to the pipe is shown in Fig. 20 (*e*). The roller is adjusted for height by nuts *a*, *a*. When a pipe runs parallel to and between floorbeams, as in Fig. 20 (*f*), a hanger of the kind shown in Fig. 20 (*a*) may have its hanger rod *b* screwed into the side outlet of a **T** *c*, which is slipped over a pipe *d* one size smaller than the run of the **T**, said pipe resting on the floorbeams, as shown. Where the beams overhead are not strong enough to support the weight of the pipes, and also where it is necessary to prevent the transmission of the sound caused by vibration of the pipes due to the movement of high-speed machinery, the pipes can be supported from the floor on standards, in the manner shown in Fig. 20 (*g*). A special hanger for large horizontal piping is shown in Fig. 20 (*h*). It is particularly suitable for a corner hanger where two long pipe lines are joined at an elbow, because the pipe can move freely in any horizontal direction. The hanger straps *a*, *a* are suspended on rollers *b*, *b* from a **T** iron track *c* along

which the hanger may roll. The track is rigidly secured by beam clamps *d*, *d* to an overhead **I** beam.

26. Exhaust-Line Support.—Vertical exhaust lines are sometimes supported at the base as shown in Fig 21, or in an equivalent manner. Into the flange *a* is screwed a plugged nipple *b* to which is attached a **T** *c* for the drip con-

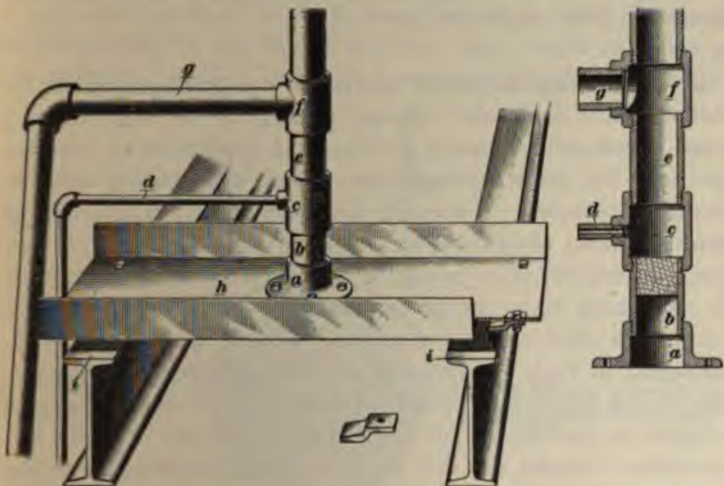


FIG. 21

nection *d*. Another nipple *e* is screwed into the **T** *c* and to it a **T** *f*, from which the pipe *g* leads to the discharge outlet of the feedwater heater or engine. The cast-iron flange *a* rests on a channel bar *h* supported by floorbeams *i*, *i*, to which it is clamped, as shown.

EXAMPLES OF PIPEWORK

RUNNING STEAM MAINS

27. Definitions.—The relatively large distributing pipes that are run in the cellar or basement of buildings for conveying steam from the boiler to different portions of the heating system, as well as the pipes for carrying the water of condensation back to the boiler, are commonly called **mains**,

the former being *steam mains* and the latter *return mains.* From the steam mains, what are usually referred to as *branches* are run to vertical rising pipes called *risers*, to which the radiators on the floors above are connected, and from the foot of which, as well as from the ends or at low points of the steam mains, *relief*, *drip*, or *bleeder* pipes are run to and connected with the return main, for taking care of the condensation from radiators, etc.

28. Arrangement of Mains.—The arrangement of the steam mains and other piping throughout a large heating plant necessarily depends on the local conditions of installation and the general requirements that such piping must be designed to meet. Generally speaking, steam mains in large heating plants should be so arranged that extensions, alterations, or repairs may easily be made when necessary, thereby obviating many inconveniences due to lack of provision for future additions or changes. Steam mains should be arranged in such a way as to obviate the necessity of shutting down the whole plant in case one of the boilers or engines is shut down for inspection or repairs. While it is desirable to make the first cost of piping installation as low as possible, the mains should be designed without undue regard to cost to give the best results for the longest period of time. Care should be exercised to make a proper selection of materials when installing a new plant or refitting an old one, the element of first cost being of minor importance compared with the possible future losses due to the use of inferior material or to hurried and hence poor workmanship.

The main piping should be as direct as possible, for the greater the number of turns and bends the more restricted will be the flow of steam through the pipe. Under some conditions, however, it is impossible to arrange the piping in the most direct line, as, for example, when a column is in the way of the main, as shown in Fig. 22, in which case it may be advisable to use special castings having flanges, as indicated by the full lines, or to use standard piping and 45° elbows, with Y fittings for the branches, as shown by the dotted lines.

The mains should be reduced gradually in size toward the end farthest from the boiler, care being taken that the reduction in area will not have the effect of decreasing the required supply of steam for radiation connected to the reduced mains. The steam and return mains are frequently run side by side, or the former above the latter, at the cellar or basement ceiling, in which case the return main is above the water-line of the boiler and for that reason is called a **dry return main.** It is also common practice to run the

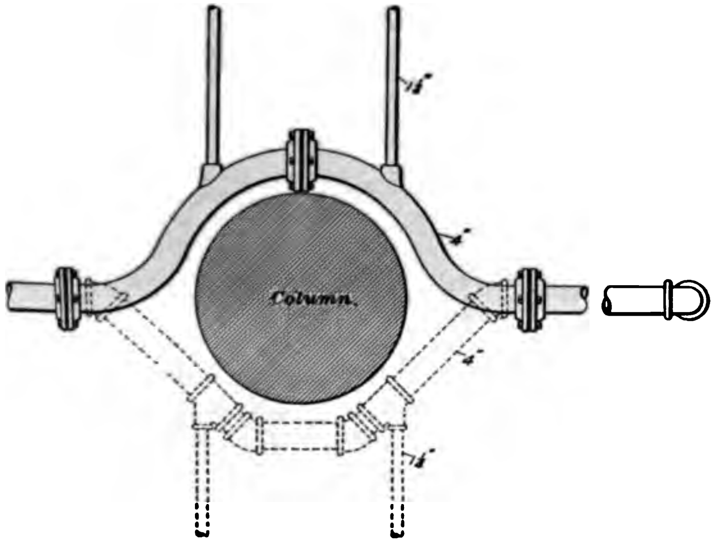


FIG. 22

steam main at the cellar or basement ceiling, with the return main at or under the cellar floor, and when the piping is so arranged, the return main, being below the water level of the boiler, is called a **wet return main.**

29. Loops Over Obstructions.—Sometimes in running mains it is necessary to clear obstructions, such as girders, machines, or doors. In such cases it frequently happens that the steam main is located at a considerable distance from the nearest return main, so that drip connections in the shape of a loop must be taken from the steam main, as shown in

Fig. 23, which illustrates how the steam main *a* may be run without interfering with the headroom of the doorway *b*. To clear this doorway, the main is looped over it by means of four 45° fittings, and to obviate water hammer by preventing an accumulation of water of condensation in the loop at *c*, two **T**'s are placed on the main and connected by the drip loop *d*, which crosses under the floor. The main at *e* must not be higher than at the elbow *c*, as, otherwise, water will not flow through the loop *d*, but will back up into the main *a*. The fitting *e* should either be level with *c* or

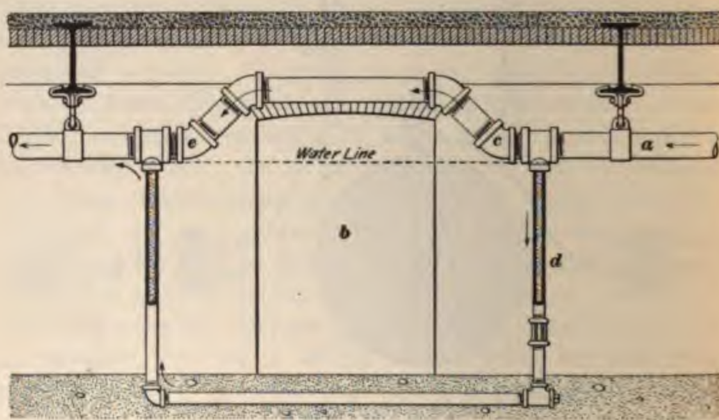


Fig. 23

slightly lower, because the **T** attached to it takes the condensation from the line *a*. Other obstructions can be looped over in a similar manner.

30. Position of Valves in Mains.—Valves in steam mains should be of the best quality, and preferably of the gate type, and be so placed as to be easily accessible. Only as many valves as are absolutely required in order to provide for all contingencies should be used.

When valves are used in horizontal steam mains, they should be placed as shown in Fig. 24, the stems standing at an angle of about 15° to the horizontal plane. Water will leak more readily than steam from the stuffingbox of the

lve, and by inclining the valve 15° or 20°, or so that the and nut is above the possible water-line in the pipe, trouble om leakage of the water f condensation is avoided. Globe valves, especially, hould not be placed in a vertical position, because when thus placed they interfere with a thorough drainage of the pipe line. Valves should be connected up so as to close against the steam pressure, in order to make easy the repacking of the valve stem while the pipe line is under pressure.

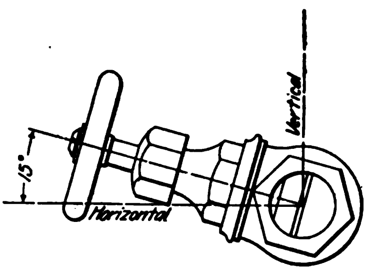


FIG. 24

31. Expansion of Mains.—Allowance for expansion and contraction is of prime importance in running steam mains, for unless adequate provision is made to allow the piping to expand and to contract alternately, something will have to give way under the stresses set up, the probable extent of the injury depending on the length of the pipe and the extremes of temperature to which it might be subjected. For example, assume that in a combined power and heating plant steam at 150 pounds gauge pressure is admitted to a main 100 feet long, the temperature of the main when erected and just previous to the admission of steam being 70° F. Steam at 150 pounds pressure has a temperature of 366°, so that the initial difference in temperature between the pipe and the steam will be $366° - 70° = 296°$, and since the coefficient of linear expansion for wrought-iron pipe per degree per foot is .00000686, the increase in the length of the pipe due to expansion will be $100 \times 296 \times .00000686 = .203$ foot, or 2.4 inches, an amount that would wrench the fittings apart, and perhaps start the joints to leaking all along the line. In actual practice, the probable amount of expansion is seldom calculated, the usual rule-of-thumb method employed being to allow 3 inches clearance for expansion for every 100 feet of pipe.

Expansion of the steam mains is generally provided for in one of two ways, viz., by means of expansion joints when no other method is feasible, or by means of bent piping in the shape of long-turn bends or goosenecks. A third method, however, is sometimes employed to allow for the expansion of the exhaust piping of large plants, a short piece of corrugated copper pipe being used in places where the available space does not permit the use of curved piping. Ample clearance should be provided at the end of a run of pipe, and branches must have sufficient length to allow the pipe to spring the required amount, or the expansion stresses will come on the fittings. Short pipes should therefore have some form of swivel connection, i. e., the number and position of the fittings used should be such as to allow for the

FIG. 25

elongation of the long run to which the short branch pipes are connected, the fittings serving as pivots about which the pipes may turn slightly without affecting the tightness of the joint. An example of a swivel connection is shown in Fig. 25, where a horizontal pipe a is placed at right angles to the main b, b and connected by nipples c, c to the elbows shown. When the pipes b, b move endwise by expansion or contraction, the nipples c, c turn slightly and thus permit the piece a to swing to accommodate itself to the change in length of b, b.

32. Flange-Union Connections in Steam Mains. When risers have been run in places before the mains are hung, it is necessary to use a flange union or a right-and-left fitting for a final connection. Thus, in Fig. 26 is shown a branch pipe a connecting the base of a riser b to a steam

main *c*, a flange union *d* being used for a final connection. A sleeve is placed in the hole in the wall, the pipe *a* passing through the sleeve loosely to provide for expansion. The flanges are screwed on the pipe so that the bolt holes are in line, the joint being made by placing a metallic gasket or some form of fibrous packing between the faces of the flanges, the bolt holes being brought into alinement if necessary, by the use of drift pins, i. e., tapering steel pins. Bolts are then passed through the holes in the flanges and

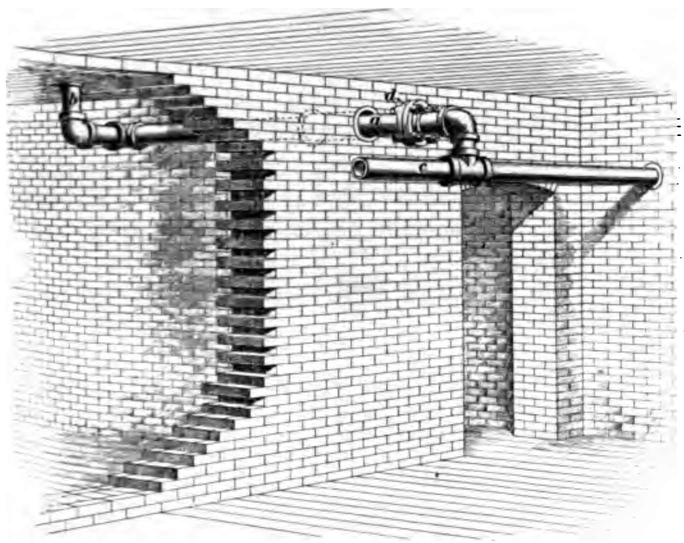


FIG. 26

screwed up tight by means of the monkeywrench. In order that flanges may match, the bolt holes must be directly opposite each other, and the rims of the flanges flush with each other. Since the holes are not always drilled true to the same circle or at equal distances apart, it is necessary to mark the flanges so as to indicate the point at which they come nearest to being in the proper position. When redrilling is necessary, or when a blank flange is to be drilled to match another, a templet *a* on which the top of the flange is indicated, as in Fig. 27, is cut out for use as a

guide in drilling the holes in the other flange, and the side of the flange union to which the templet is fitted should be

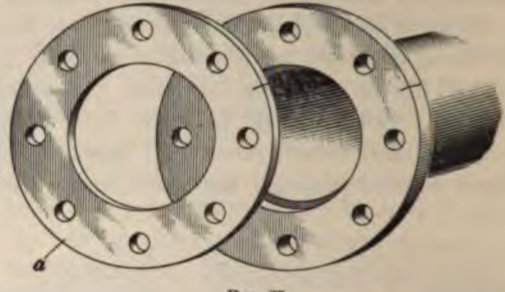


FIG. 27

plainly noted on the templet, as otherwise the two halves could not be put together.

33. To put flanges on pipe requires the use of chain tongs, as the common pipe tongs are not large enough to grip them. Fig. 28 shows how the flanges are screwed on; the chain is fitted around the flange as well as possible, the chain bearing against the bolts when a good grip cannot be had on the flange; the chain is hooked to the claw on the handle, and wound around the lever to hold the chain in place; the toothed end of the lever to which the chain is attached is then forced against the edge of the flange. Another pair of tongs is clamped around the pipe to operate in the opposite direction, and

FIG. 28

is held to prevent the pipe from turning while the flange is being screwed on.

Flanges may also be screwed on the ends of pipes by inserting two bolts or pins in the bolt holes of the flange and applying a bar between.

34. A properly made flange joint will be steam-tight and reasonably permanent. In making a flange or large screw joint, the surfaces should be thoroughly cleaned, so that no foreign substances may prevent the threads from coming in contact with one another all around the pipe in the screw joints, nor prevent the faces of the flanges from pressing evenly against the packing, whatever kind it may be. Another important point in making a flange joint is to see that the two lengths of pipe are in line with each other. A great many times the cause of leaky joints is attributed to the packing, and it is said to be too soft or too hard, too thick or too thin, when really the cause of the trouble could be traced to a lack of true alinement.

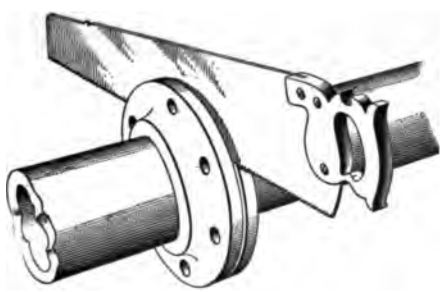


FIG. 29

When horizontal pipes are out of line vertically, they can, as a rule, be straightened more readily than when out of line sidewise, especially when they are suspended from the ceiling by adjustable pipe hangers. Long lengths of piping can generally be straightened more readily than short ones, owing to their greater flexibility.

A flange joint located about the middle of a long line of large pipe, where the faces of the flanges are parallel and close together, is a difficult one to repack. The most difficult part of the work is the removal of the old gasket, which has become hardened by the heat and adheres firmly to the flanges. The pipe can seldom be moved endwise more than

$\frac{1}{16}$ inch, so that it is impossible to remove the gasket by chipping or filing. In this case an old hand saw will be found an excellent tool to use in the manner illustrated in Fig. 29. The saw is guided by the flanges and generally leaves a smooth, clean surface for the new gasket. When inserting a new gasket, it will be easier, and better for the gasket, to insert it from the bottom. This may readily be done by tying a string to the gasket, and then pulling it up between the flanges, as shown in Fig. 30, and inserting one of the upper bolts. The others can then be put in and the flanges drawn together. Gaskets have frequently been injured in places of this kind by attempting to push them in sidewise or to poke them into place by means of a wire or a thin strip of iron or steel.

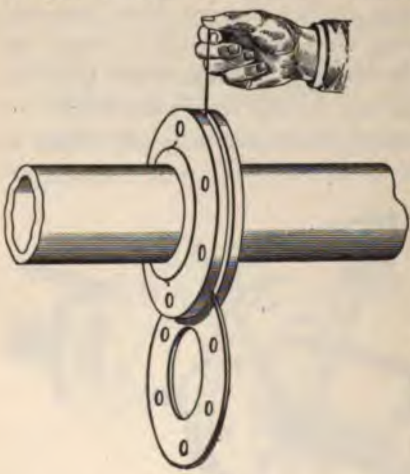


FIG. 30

A simple and quick method of cutting gaskets for pipe flanges consists in laying the sheet of packing over the flange, and taking a hammer and striking the packing over the edge of the flange when the edge will be found to cut through the packing. When cutting the bolt holes, use the peen of the hammer, permitting the peen to fall squarely over the hole. The result thus produced will be found to resemble closely that of a punch. After cutting one hole on opposite sides of the sheet, drop a bolt into the holes to prevent the packing from moving, which will insure the remainder of the holes coming in the proper place. Gaskets cut in this manner never fail to fit exactly when placed in position in the joint.

When cutting rubber packing with a knife, dip the blade into water in which a little sal soda has been previously dissolved. This makes an excellent lubricant for this purpose.

Sheet asbestos softens quickly when saturated with water or boiled linseed oil and is a useful material for uneven joints, as it yields under the tightening of the bolts so as to fill any depressions.

All joints, except very thin putty joints, should be well tightened when the pipe is put up and when the joint is first made, and after the joint has become thoroughly hot the bolts should be again tightened slightly. This is particularly the case when soft packing is used, such as sheet rubber and asbestos.

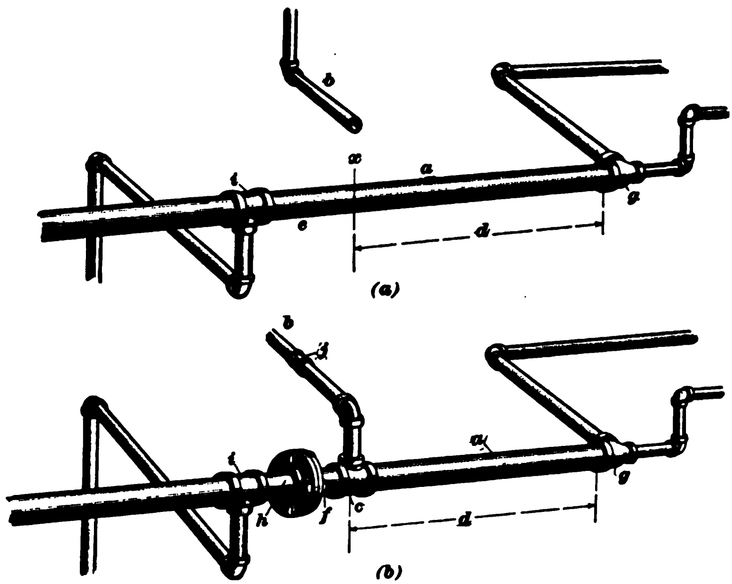


FIG. 31

When putting up a large steam pipe having flanges screwed on, a thoroughly tight joint may be had by putting in a copper gasket, preferably corrugated, $\frac{1}{32}$ inch thick (instead of rubber), between the flanges, provided that the latter are true and smooth on the faces.

35. The manner in which a flange union is employed for making final connections in a steam main that requires cutting in order to insert a fitting is shown in Fig. 31. The

steam main *a* before cutting is shown in Fig. 31 (*a*); it is required to connect the riser *b* to the main in the manner shown in Fig. 31 (*b*). The **T** *c* to which *b* is to be connected is placed against the main in line with *b*, and a chalk mark is made at *x* to show where it is to be cut. After the main is cut, the parts *d* and *e* are unscrewed from their fittings, the cut end of *d* is threaded, and the **T** *c* screwed on. A nipple *f* taken from stock or made on the premises and one-half of the union are then attached to the **T** *c*, and the pipe *d*, which now carries the **T** *c*, the nipple *f*, and half the union, is screwed into its fitting *g* until it is tight and the side outlet of *c* pointing directly upwards. The second half of the flange union is then held in position by hand to allow the exact length of the nipple *h* to be measured. This nipple is then cut to length, threaded, and screwed tightly into the flange, and finally screwed into the **T** *i*. A gasket is now inserted between the flanges of the union, which is then bolted together. The riser *b* is now connected to *c*, placing a right-and-left coupling at *j*. Flange unions are generally used for pipes 2 inches or more in diameter.

36. Leaking Threads.—It frequently happens that threaded joints leak steam and water. If the joints are new, they frequently *take up*, as it is called, that is, become tight without repairs. If, however, a leak occurs in an old screw joint, the joint seldom takes up and requires to be renewed. Small leaks in new screw joints can usually be calked and made permanently tight. Large leaks, however, are sufficient cause for renewing the joint.

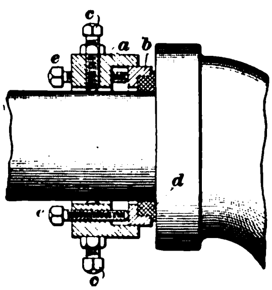


FIG. 32

Frequently a large pipe, such as a steam main, will spring a leak in the thread at a fitting, and permanent repairs cannot be made without shutting down the plant. As it is not always possible to do this, temporary repairs are frequently made. While cements applied externally will

sometimes stop leaks in low-pressure pipes, it is advisable not to depend on them too much. A good clamp, with means for compressing a gasket against the pipe and fitting, should be used instead. Fig. 32 shows such a clamp, or **leak gland.** The clamp *a* and gland *b* are each made in two pieces and hinged. The clamp is firmly attached to the pipe by screwing up the setscrews *c*, *c*. The gasket *d* is pressed tightly around the leaking thread by screwing up the setscrews *e*, *e*, and thus the leak is stopped. As the joint may be nearly corroded through, if the pipe is an old one, it is advisable to put in a new piece of pipe as soon as it is convenient to shut off steam.

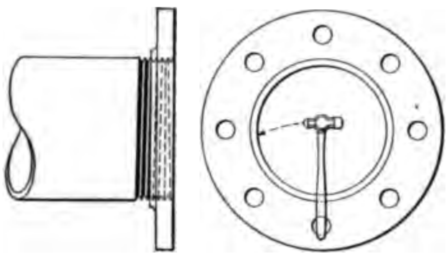


FIG. 33

In some cases where flange joints are used, the pipe may leak where it is screwed into the flange. Repairs can be effected by peening the end of the pipe with the ball of a ball-peen hammer, as shown in Fig. 33, peening lightly all around the inside of the pipe and thus expanding it tightly into the thread of the flange.

37. Use of Couplings in Mains.—In places where it is necessary to connect lines of pipes that come together from different directions, also when it is necessary to insert a fitting or remove a defective piece of pipe from the center of a run, a right-and-left coupling may be used for connecting the pipes, as shown in Fig. 34. The pipes *a*, *a* to be joined are threaded, as shown in Fig. 34 (*a*), with a right-hand thread on one end and a left-hand thread on the other. In order that both threads on the pipe may make up tight at the same instant, the coupling is first screwed on the right-hand thread, as shown in Fig. 34 (*b*), by hand, counting the number of turns that can be made as the coupling is removed. The operation is then repeated on the left-hand thread, as

shown in Fig. 34 (*c*). The coupling should be started on the longer thread first, and given a number of turns equal to the difference of the number of turns it could be screwed by hand on the right-hand and left-hand threads, respectively. The pipes are then brought together, as shown in Fig. 34 (*d*), with the free end of the pipe firmly against the coupling, which is then screwed up by hand and finally tightened by pipe tongs or a pipe wrench. The form of connection made

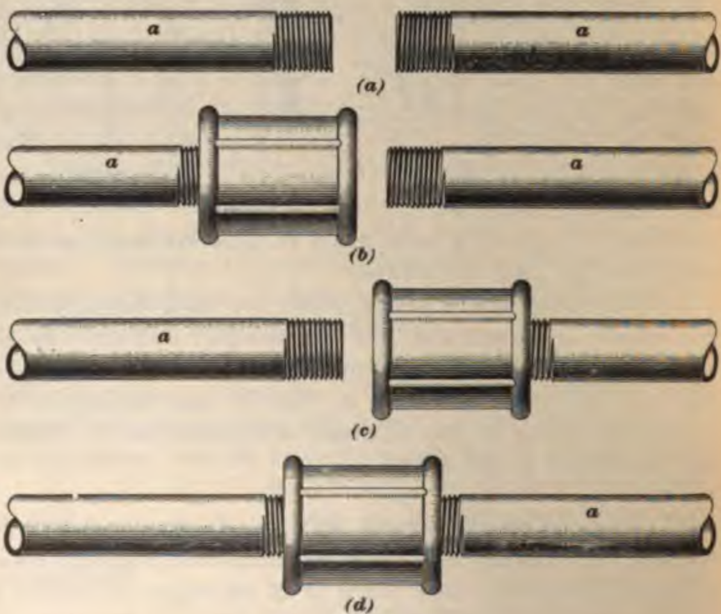


FIG. 34

by a right-and-left coupling cannot always be used, but is a very satisfactory one for pipe lines of $1\frac{1}{2}$ inches or less in diameter, making a joint little liable to leak. Threaded unions with a gasket between the two halves should never be used in steam-fitting work, because such joints will not remain steam-tight.

38. Relays.—When a main or any horizontal steam-supply pipe has to be run a long distance, it becomes

impracticable to grade it uniformly throughout its whole length, because the far end drops too low to be drained conveniently. In such a case, the difficulty may be overcome by introducing vertical offsets, or **relays**, in the line of pipe, as shown in Fig. 35. A relief pipe may then be attached at the foot of each offset, as at *a*. The steam should always flow down grade, that is, in the direction of the arrow.

BRANCH CONNECTIONS

39. The connecting pipes between mains and risers are commonly called **branches**, the branch connection between the steam distributing main and the riser being referred to as the *steamer-riser connection*, the branch between the return riser

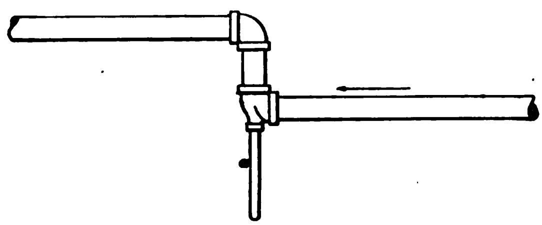


FIG. 35

and the main return being known as the *return-riser connection*. Branch connections from mains to risers are run from the top. side, or bottom of the main, or at an angle thereto, as may be required. By taking the branch from the top of the main, the water of condensation flowing along the bottom of the main cannot enter the branch with the steam, and the branch and riser can drain back into the main.

40. Long branch connections may be made to the steam main *a* in the manner shown in Fig. 36 (*a*), where the branch *b* is long enough to spring sufficiently to take care of the expansion of the riser *c*, and where the latter will permit sufficient springing to make the final right-and-left coupling connection. In Fig. 36 (*b*) the elbows *d* and *e* provide for the expansion, the elbows having a hinge-like action when under the stress caused by the expansion of the riser, and

this prevents the connecting pipe *b* from being sprung when the riser *c* expands downwards. Where the branch connections are short, the connections shown in Fig. 36 (*a*) cannot be used because of the stress on the elbow at the bottom of the riser, due to its downward expansion, and hence the connection shown in Fig. 36 (*b*) is used, an ordinary amount of expansion being thereby provided for in all directions. The final right-and-left coupling connection may be made in the most convenient place, which, according to circumstances,

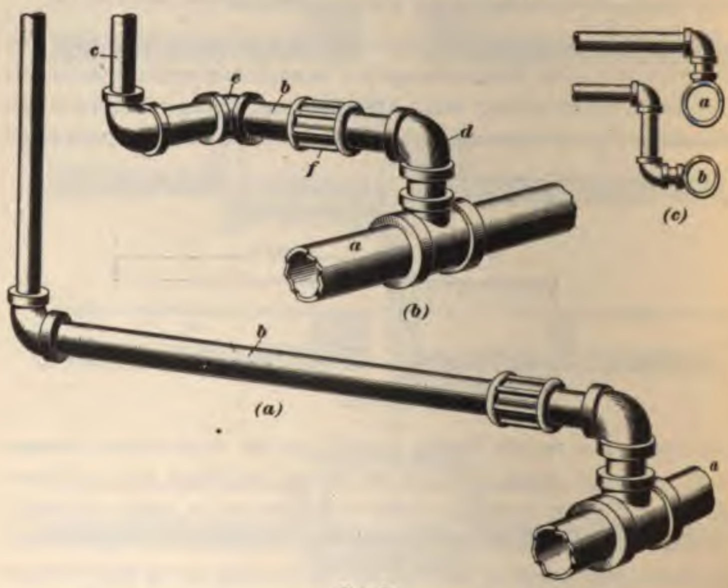


FIG. 36

may be near the riser or near the main. In two-pipe steam-heating systems, where the steam is conveyed to the radiators through one pipe and the water of condensation taken away through another pipe, the steam main *a* may be run above the return main *b*, as shown in Fig. 36 (*c*). In that case the branch connections may be made to the top of the steam main and the side of the return main, as shown.

A method of connecting a branch to a riser from the side of the main, the branch draining to the riser, a drip or relief

pipe being connected to the return main above the water-line in the system, is shown in Fig. 37. The return pipe *a* is carried on the side wall above the boiler water-line, the drip pipe at the foot of the riser *b* having an enlargement to prevent the water that falls down the riser from trapping the steam in the branch connection and preventing it from flowing freely into the riser. The enlargement of the upper end of the drip pipe is accomplished by using a regular full-size **T**, into which is screwed a nipple, at

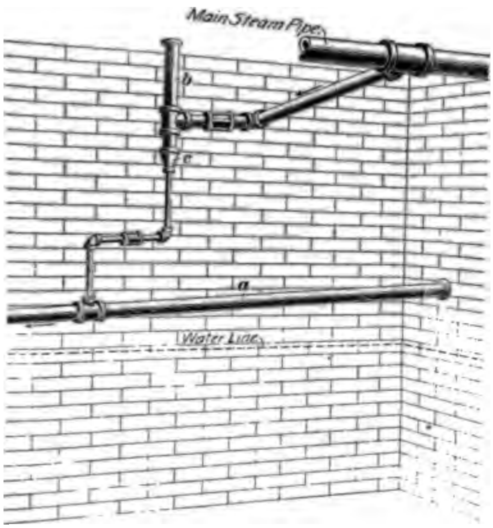


FIG. 37

the lower end of which is placed the reducing coupling *c*. Water of condensation in the main steam pipe flows to some point where it may conveniently be drained into the return.

41. Fig. 38 shows a branch main *a* connecting to a riser *b* from which a drip pipe *c* is carried downwards and connected to the return pipe *d* at the floor, making what is called a *sealed-return* connection, because the water level in the drip pipe will be between the return main and the steam pipe *e*, as indicated. As the steam main *e* lies close to the

ceiling, the branch *a* cannot be taken from the top but must be taken from the bottom of the main, the water of condensation draining through the branch to a reducing **T** *f* from which the drip pipe is carried down near the wall, so that it will not be in the way. The drip pipe is connected to the return pipe *d* in the manner shown by the illustration to allow for expansion and also to permit of easy con-

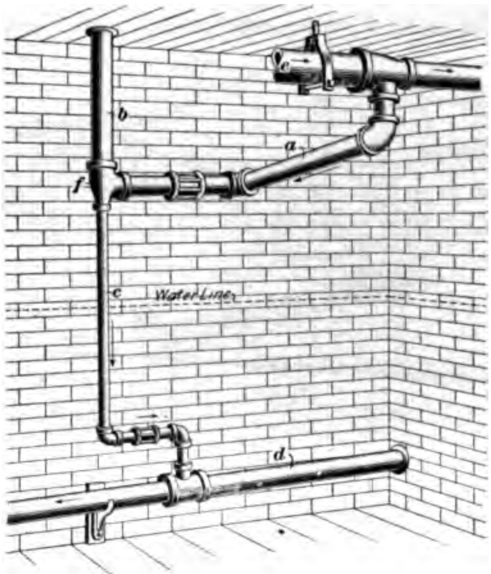


FIG. 38

nection. The drip pipe may be run straight into the return main, but this permits neither free expansion nor ready connection.

42. The method generally followed in taking a branch *a* from a main *b* at angle of 45° is illustrated in Figs. 39 and 40. The **T** on the steam main *b* is so placed as to allow the use of a 45° elbow and nipple in making up the branch, which is then carried over to the riser *c*, as shown. Instead of using a reducing coupling at the bottom of the riser, an elbow *d*, with a small outlet for the drip-pipe connection, is used,

the return main *e* being suspended from the ceiling either beneath the steam main, as in Fig. 40 (*a*) or at the side of the main, as in Fig. 40 (*b*).

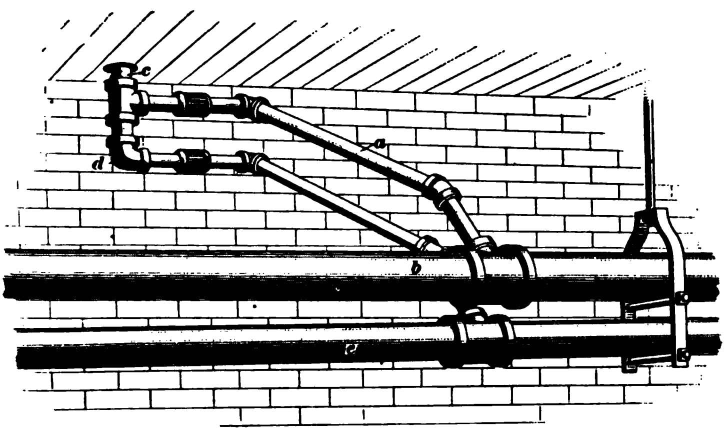


FIG. 39

When the supply and return mains run side by side at practically the same level, the drip or relief pipe may be

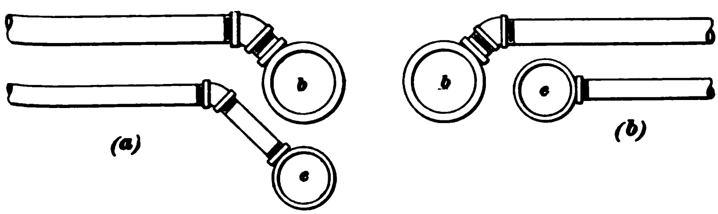


FIG. 40

connected into the side of the return, as shown in Fig. 40 (*b*), an elevation of the connections shown in perspective in Fig. 39 being illustrated by Fig. 40 (*a*).

RISER CONNECTIONS

43. Definitions.—The term **riser** is used to designate vertical lines of pipe, the *steam riser* being the specific designation for the pipe that carries the steam vertically from

the distributing mains in the cellar to the radiator connections, while the term *return riser* is applied to the pipe that carries the condensation from the radiators back to the main return pipe.

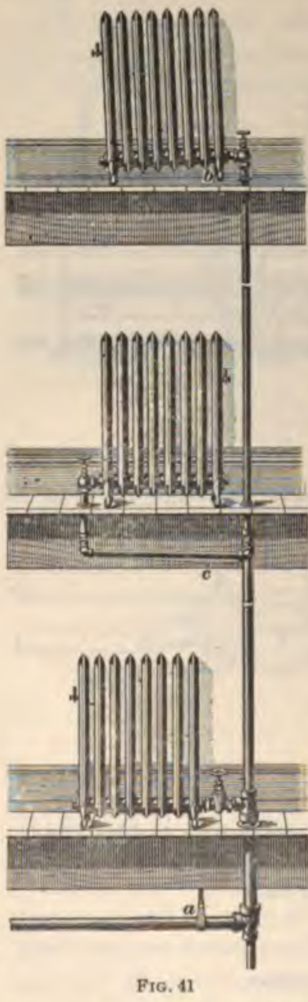


FIG. 41

44. Expansion of Risers. One of the principal requirements in running risers is that adequate provision be made for their expansion and contraction, thereby relieving them of any stress that might be thrown on them through the use of improper radiator connections. The effect of the expansion of risers is clearly indicated in Fig. 41, which shows how the upper radiator, being connected directly to the riser rigidly supported by the hanger *a*, is lifted from the floor at *b*. The riser shown may be assumed to be 40 feet long, and if the piping was erected in winter at a temperature of 32°, the riser would expand upwards slightly more than $\frac{5}{8}$ inch if steam at 5 pounds gauge pressure and having a temperature of 227° be admitted to the line, the actual amount of movement due to expansion being found, in inches, by multiplying together the length of the pipe, in inches, the number of degrees it is increased in temperature, and the coefficient of linear expansion, which, for wrought iron, is .00000686; thus, $40 \times 12 \times (227 - 32) \times .00000686 = .6427$ inch, or $\frac{5}{8}$ inch, full.

45. By inserting in the riser, approximately at the center of its length, a loop such as that shown in Fig. 42, the point of support being at *a*, expansion may take place upwards or downwards equally without affecting the radiators, which in most cases should be connected to the riser by means of a spring piece *c*, as shown in Fig. 41 under the middle radiator, although a short, rigid connection may be permitted when the radiator is located within a foot or two of the point of support from which the pipe expands. The elasticity of the spring piece *c*, Fig. 41, which is connected up with three elbows and two nipples, as shown, compensates for the expansion of the riser under ordinary conditions, while the pitch of the spring-piece piping is such as to give a free, easy flow of condensation from the radiator to the riser, avoiding trouble from water hammer. In order to avoid pockets in which water of condensation may accumulate, the piping of the loop illustrated in Fig. 42 should have a downward pitch throughout its length when the limit of expansion of the riser is reached. The pitch of the piping of the loop is indicated by the side view given.

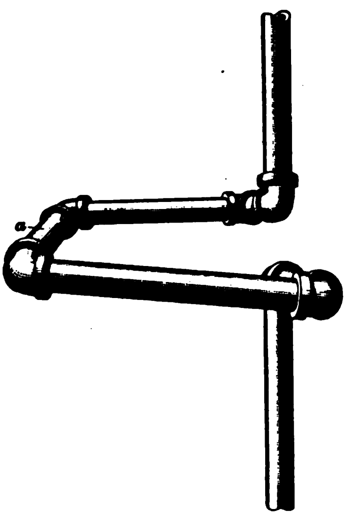


FIG. 42

46. Provision for the expansion of rising lines may also be made by using a spring or return bend in the manner illustrated by Fig. 43, the radiator connections near the point of support being taken directly from a cross in the riser, as any upward movement of the lower part of the riser due to expansion will be absorbed by the spring of the return bend. The riser above the loop is supported on the floor thimble by a sleeve under the cross.

47. In the overhead system of steam distribution that is frequently employed in the heating of tall buildings, a single large riser is usually carried upwards through the elevator shaft from a low-pressure header or receiver in the boiler room to the attic or to a specially arranged space, called a *pipe chamber*, near the top of the building. In this space the riser is connected to a system of mains that supply drop

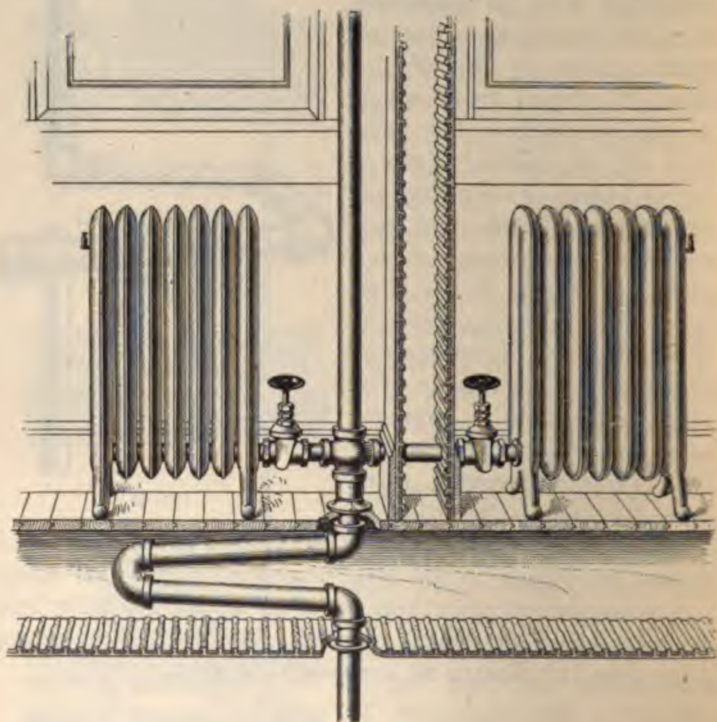


FIG. 43

risers in the manner indicated in Fig. 44. Provision for the expansion of the drop risers, one line of which is shown in Fig. 45, is made partly by the character of the connection to the main in the pipe chamber and partly by an expansion joint located about the middle of the drop riser, the pipe being supported in two places, which are midway above and

below the expansion joint. One half of the expansion of the riser is taken up by the expansion joint, and the other half is taken care of by the springing of the connections at the top and bottom of the riser.

It frequently happens that hangers must be located on horizontal connections . that are moved vertically by expansion; hence, compensating hangers are required in order to obtain a nearly

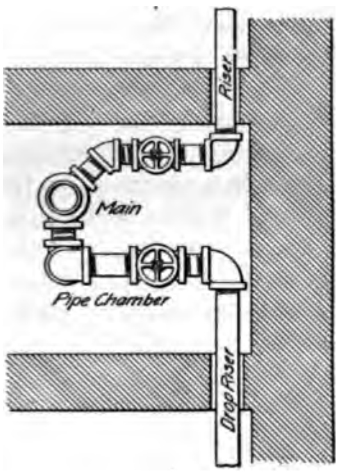


FIG. 44

steady stress on the hangers. Such hangers are usually of the helical spring type shown in Fig. 46. If compensating hangers are used in an installation like that shown in Fig. 45, they should be placed at *a* and *b*, the one being located in the pipe chamber to support the riser at the top and the other in the basement to support the base of the riser.

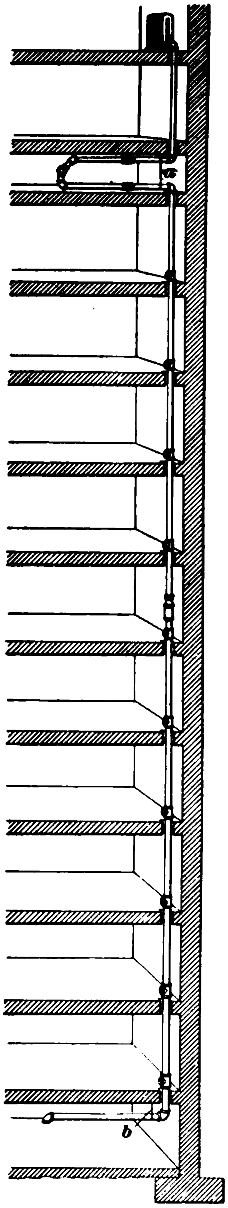


FIG. 45

48. Concealment of Risers.—The concealment of risers in office and other buildings of steel fireproof construction is often a perplexing problem on account of the obstructions by girders, etc., which prevent placing the risers close to the columns. Such concealment is in many cases absolutely necessary, however, and in running rising lines alongside of steel columns, one of several methods, some of which are shown in Fig. 47, may be used with satisfactory results. The column is usually partly protected from the expanding influence of the heat of the riser by means of clay or tile fireproofing, the piping being carried upwards in recesses into which, if such recesses are not otherwise accessible, it is comparatively easy to break if necessary. The concealment of risers in wooden walls necessitates the use of covering on the pipe to prevent its coming in contact with, or charring, the woodwork.

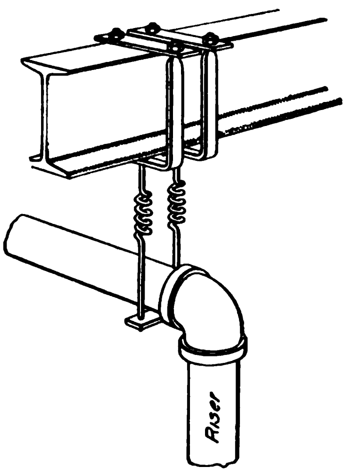


FIG. 46

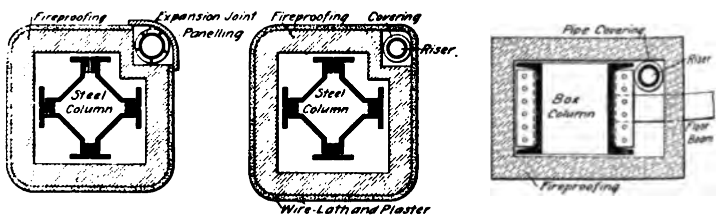


FIG. 47

49. Offsets in Risers.—In erecting risers, it is often necessary, where the upper walls are recessed, as shown in Fig. 48, to carry the riser backwards by making an offset, either by bending the pipe or by using 45° elbows as shown. If possible, the offsets should be made under the

floor, but as this is not always convenient, they are frequently made above the floor. In one-pipe work it is not advisable to make offsets with 90° elbows, but where 90° offsets must be made, long-turn elbows should be used, or the horizontal run of the offsetting pipe, as well as the elbows thereon, should be one full size larger. The best method of making offsets in single-pipe work is by the use of 45° elbows, but it is not always convenient to use them.

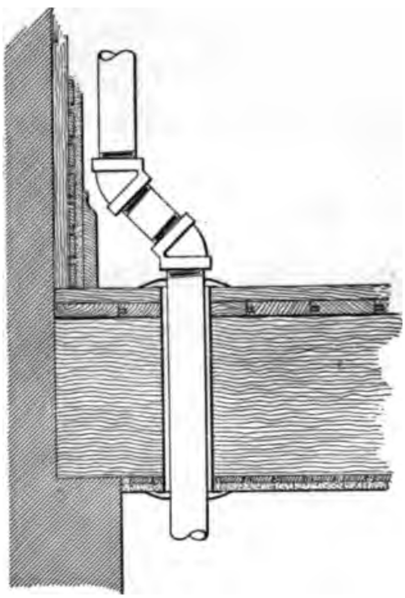


FIG. 48

Horizontal offsets in single-pipe work should be made in the manner indicated in Fig. 49 (*a*), the reason for increasing the size of elbows and horizontal pipe being to obviate retardation of the flow of steam. If a pitch of 1 inch or more per foot can be given to the riser connections, it is customary to make the inclined pipe the same size as the riser. Water of condensation dropping down the riser from the radiators will gather and produce water hammer if the downward expansion of the riser forms a trap, as shown in Fig. 49 (*b*). If the horizontal pipe is too small, the steam flowing upwards will hold the water back, completely filling the pipe at the elbow, and thereby cutting off the supply of steam to radiators above the offset. This difficulty is found only where the piping is too small, or where the horizontal pipes have not enough inclination to drain properly.

When offsets are used for the purpose of providing for the expansion and contraction of risers, great care must be exercised in running the pipes so as to secure adequate drainage

of each pipe and thereby obviate all difficulty from water hammer arising from the formation of pockets.

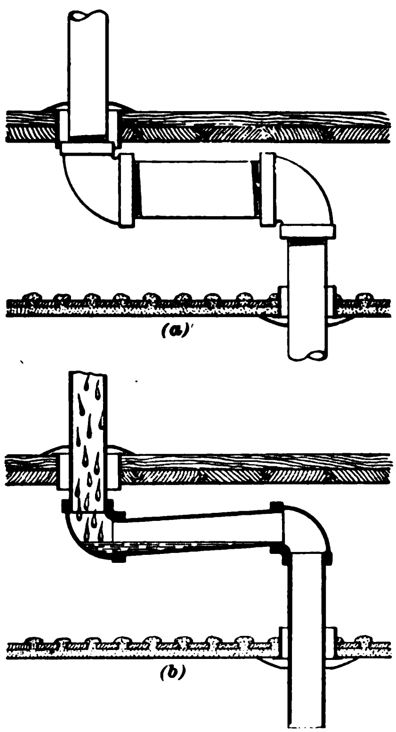


FIG. 49

RADIATOR CONNECTIONS

50. Single-Pipe Connection.—One way of making a single-pipe supply connection to a radiator from a main above it, draining the branch through the floor, is illustrated in Fig. 50. The radiator is located above the water-line of the boiler. The steam main is shown at *a*; the branch *b* feeds the riser *c*. The connection *d* from the riser to the radiator is carried above the floor and pitched down toward the riser. The water of condensation flowing into the reducing **T** at the foot of the riser is carried away by the drip pipe *e* attached thereto. Some pipe fitters claim that the better practice is to make the **T** full size and reduce beneath the floor with a reducing coupling or elbow.

51. Two-Pipe Connections.—In steam-heating systems, the radiators are often connected by a separate steam-supply pipe and return pipe to the main piping. The steam-supply pipe is usually connected to one end of the radiator, and the return pipe or drip to the other end of the radiator, so that the flow of the water of condensation does not interfere with the flow of the steam. In this method of connecting radiators, smaller pipe than can be used with

single-pipe connections may be employed, for with the one-pipe connections the water of condensation and the steam have to flow through the same pipe, making a large, free opening imperative. Either system of connecting up may be used with good results, provided that the connections are large enough to allow the condensed water to flow from the radiator without cutting off the steam supply; the ease with which the one-pipe connection can be shut off makes it very popular. Two-pipe radiator connections may be used either with the one-pipe heating system or the two-pipe heating system.

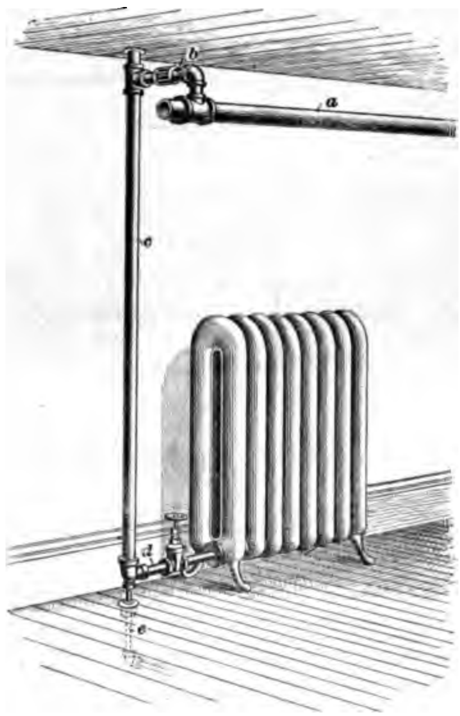


FIG. 50

52. When a radiator or coil is located below the water-line of the boiler, as indicated in Fig. 51, it may be connected so that by closing one valve and opening another, the water of condensation may be caused to pass through the coil. When the valve *a* is closed, there is no circulation in the coil, which is full of water, but when the valve *a* is opened and the valve *b* closed, the hot water of condensation from the main and riser flows through the coil, the cold water therein falling by gravity into the drip pipe and thence flowing into the return main and back to the boiler. It is not considered advisable to connect radiators to

a riser in the manner shown, unless they are of the hot-water pattern, having the flow connection at the top and the return at the bottom. The valve *b* in the riser can be dispensed with, but in that case the circulation is not as positive as otherwise.

53. Wall radiators are usually attached to walls so that the center of the tappings are about 3 inches from the

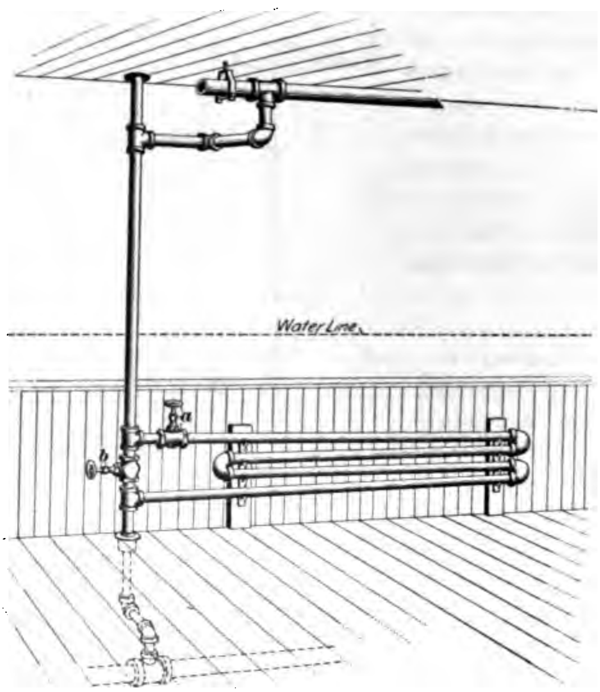


FIG. 51

finished walls. As this is about the distance that a riser is located from the wall, a straight connection can be made if the expansion is taken up elsewhere, or if the branch is long enough to spring sufficiently to compensate for the expansion. If the radiators are set in window recesses, and the risers are run on the face of projecting piers, the connections may be made as shown in Fig. 52. Iron girders, shown by dotted

lines, are supported by the piers on each floor. The risers are run vertically one on each side of the girder, as shown. The radiator steam connection *a* is offset around the corner of the pier and forms a swivel-joint for expansion. The return connection offsets around the next pier. This connection should be used where possible. In making connections to long wall radiators at the printing plant of the International Textbook Company, at Scranton, Pennsylvania, provision for expansion was made by coupling up in the manner illustrated in Fig. 53 (*a*) and (*b*), the position of the riser being such that a sightly or more suitable double swing could be obtained in no other way. The wall radiators are mounted in hangers especially designed to permit them to move

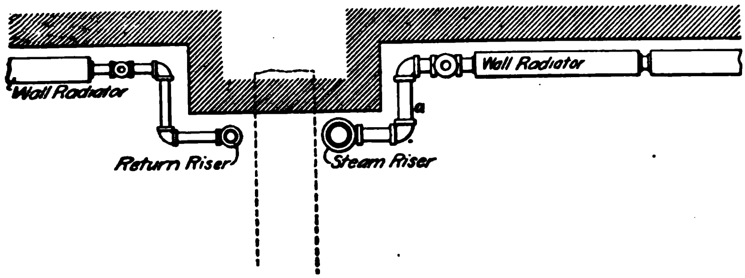
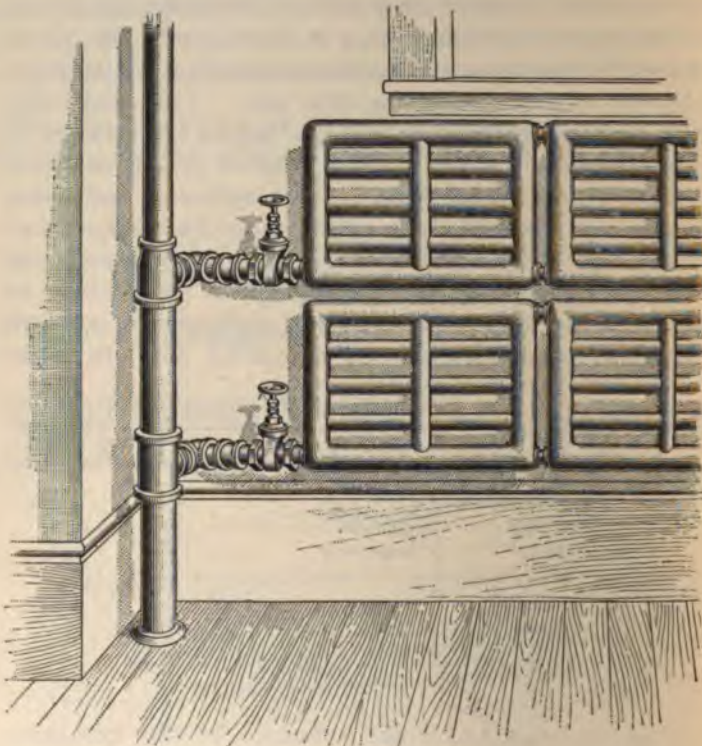
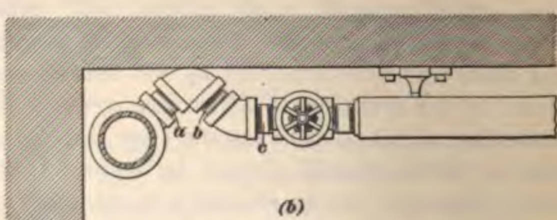


FIG. 52

freely up or down under the influence of the expansion or contraction of the risers should excessive stresses come on them. To provide for the ordinary amount of expansion, which is small, a 90° elbow, a 45° elbow, and three close nipples *a*, *b*, and *c* are placed as shown. The risers are short and are supported by 45° elbows resting on floor plates on the first floor. No severe stress is therefore thrown on the connection between the riser and the radiator, the joints of which should always be tight. In order to secure the greatest possible elasticity in so short a swivel connection, which would otherwise be too stiff to readily compensate for the upward or downward movement of the riser, the close nipples *a*, *b*, and *c* are of brass, the final connection to the radiator being made by means of a ground



(a)



(b)

FIG. 53

union on the radiator gate valve, the tail of which is screwed directly into the radiator. This form of connection is not suitable for tall buildings.

54. In Fig. 54, the steam supply riser *a* and the return riser *b* are shown as being run side by side, such being considered the best method. To insure neatness, the branches are carried under the floor, as shown, to conceal them, and only the valves interfere with sweeping the floor. When the branches are run above the floor, more or less dirt always

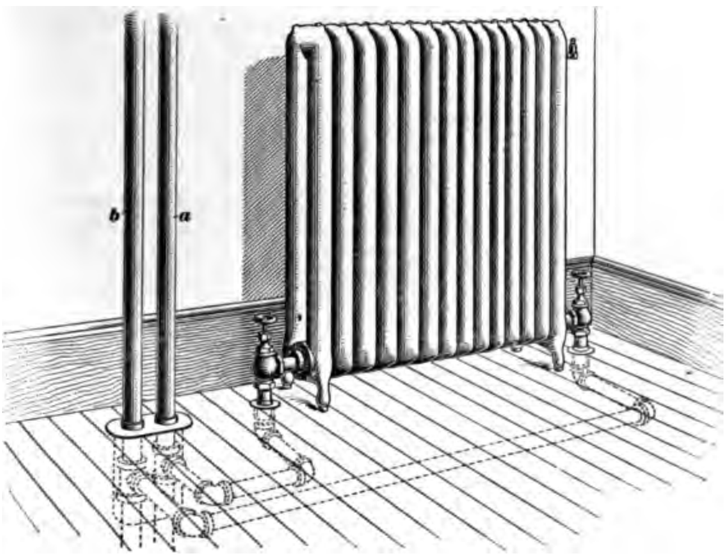


FIG. 54

collects around them, unless the radiator is made with high legs. The supply and return connections are arranged to allow for expansion, and are graded downwards toward the riser, so that when the latter expands upwards the branches will not be shifted so as to form pockets in which sufficient water will be held to shut off the steam. Water pockets cause the steam to bubble through the accumulated water, resulting in surging and explosive, or pounding, noises, a difficulty that is liable to rupture the fittings or damage the apparatus.

55. Two-pipe radiator connections placed above the floor should be run as close to the wall as the pipe will permit, offsets made with fittings being used, as indicated in Fig. 55. The **T** on the steam-supply riser *a* turns toward the radiator, a nipple, a gate valve, another nipple, a 45° elbow, another nipple, and a 45° elbow, being used in the order named, in running back of and to the rear end of the radiator, where an elbow and nipple and a right-and-left elbow bring the pipe connection opposite the opening in the radiator; here the

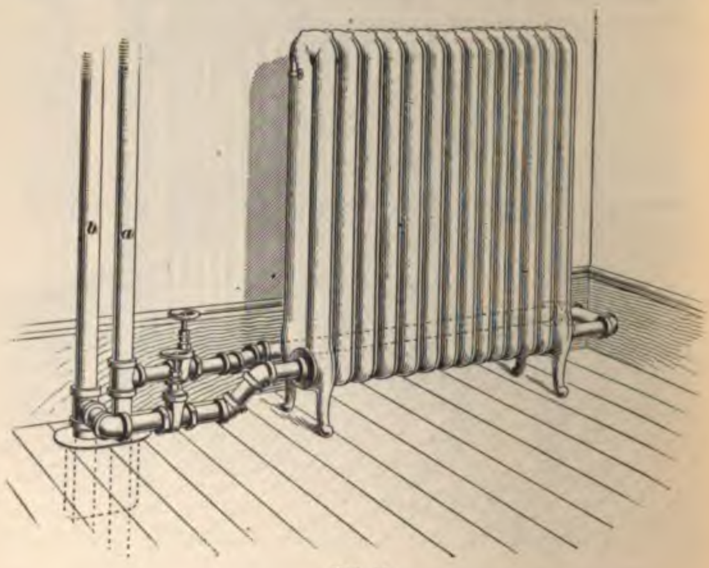


Fig. 55

final connection is made with a right-and-left nipple. The supply connection may drain to either the radiator or to the riser; if drained to the radiator, the outlet **T** in the riser should be kept high, while if drained to the riser, the **T** must be kept low down. The return connection is then run in the same direction, an elbow and close nipple connected to the **T** in the return riser permitting the return pipe to pass in front of the steam riser. A short pipe is screwed into the elbow, and connects with the return valve, which should be

placed close to the steam-supply valve, on the radiator side of which the connection is made up of a nipple, 45° elbow, another nipple and 45° right-and-left elbow, and finally a right-and-left nipple, in the order named.

56. A method of making connections to two radiators from one riser, under a floor of typical fireproof construction,

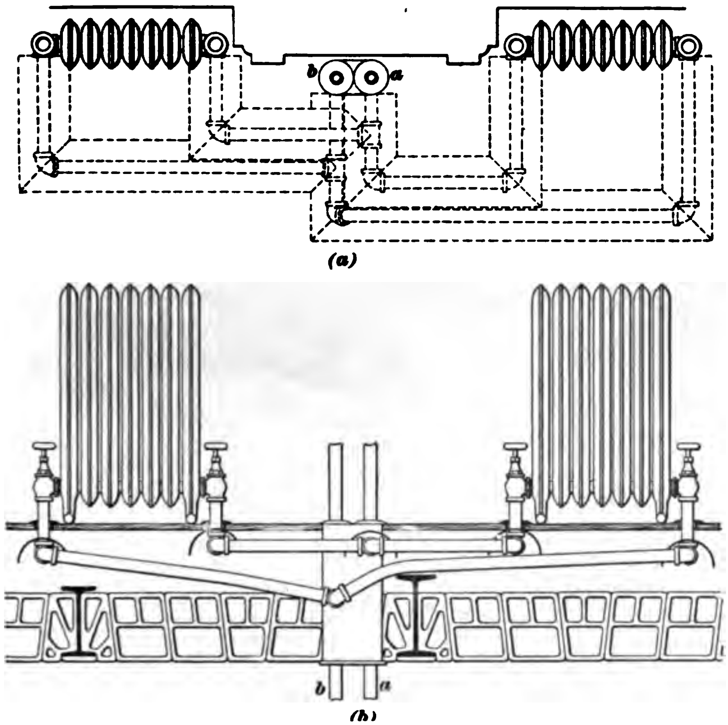


FIG. 56

having terra-cotta flat arches and wood sleepers, to which the flooring is nailed, is illustrated in Fig. 56 (*a*) in plan view and in Fig. 56 (*b*) in elevation. It sometimes happens that the steel beams are deeper in some places than others, and Fig. 56 illustrates such a condition of things. The steam and return risers *a* and *b* are run side by side, and the branch connections thereto are placed low enough to drain into the

risers when lifted upwards by the expansion of the risers. The return enters the return riser at as low a point as possible, so that the steam-supply branch will pass over it, and not interfere with the expansion of the steam riser or branches. The connections close to the radiators are made in the manner previously described. Where a beam lies close to the floor line it interferes with the pitch of the return connection, and it may be necessary to bend the pipe, as shown

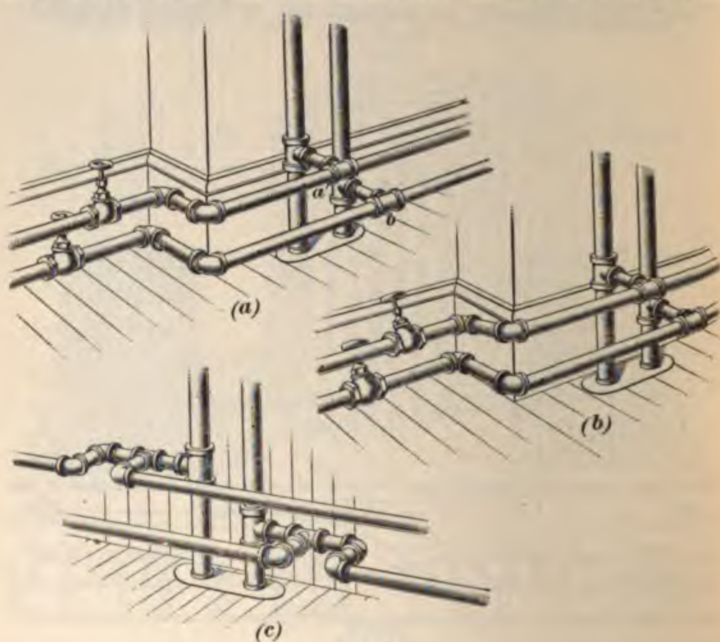


Fig. 57

in the illustration, or make the offset with fittings; at any rate, the return should have a good inclination back to the riser and yet come clear of any obstructions that would interfere with expansion.

57. The wrong and right methods of running connections above the floor to two radiators supplied by a single riser are shown in Fig. 57. Referring to Fig. 57 (*a*), it will be seen that into the **T** outlets of the supply and return risers

are screwed nipples attached to the T's *a*, *b*. The branches are run from the outlets on the run of the bull-headed T's *a*, *b*. The radiators being located in the recess of windows, offsets are made with 90° elbows, as shown, one above the other. This is a poor way to make connections, as the expansion of the risers, if upwards, will raise the T's and cause the branches to move pivotally on the elbows, as indicated in Fig. 57 (*b*), thus trapping the connection, and thereby stopping the circulation to the radiator. The use of T's in the manner shown is particularly objectionable, as the water or steam is liable to flow more freely to one side than to the other, thereby cutting off the supply of steam to one of the radiators or interfering with its flow. A better method of making the connections is shown in Fig. 57 (*c*), a better working job being secured by the connections, which can be made to look quite as neat. This method is particularly advantageous if there is no recess to admit swivel-joints to accommodate expansion.

PIPE COILS AND CONNECTIONS

58. Coils are constructed by the pipe fitter in the shop or at the job in various ways and to meet different requirements. In making the trombone or return-bend coils, short pipes are used with the ordinary close, open, and spread patterns of return bends. The close-pattern return bends are used where the pipes are short, and have right-and-left threads; hence, the pipes are threaded with a right-hand thread on one end and a left-hand thread on the other. The first pipe of the coil is screwed to a return bend, as *a*, Fig. 58 (*a*), and the next pipe is then screwed into the other outlet of the bend, and also at the same time into another bend *b* at the other end of the pipe in the same manner as in making up a right-and-left coupling. For holding the return bends, a box wrench, shown in plan and elevation in Fig. 58 (*b*), which fits over the bend, is used. The reason for making the right-and-left connection is that the pipes are too short to be sprung so that the return bend will pass the

adjacent fitting. If, however, the pipe is long enough to be sprung so that the bend in screwing on will pass the adjacent fitting, right-hand connections may be made, the pipes being sprung and held by a block of wood, while the box wrench is used in screwing on the fittings. It will be noticed that the lever handle of the wrench is so shaped as to clear the fittings when turned. When the pipes are of large diameter, the coil must be made up of long and short pipes, as indi-

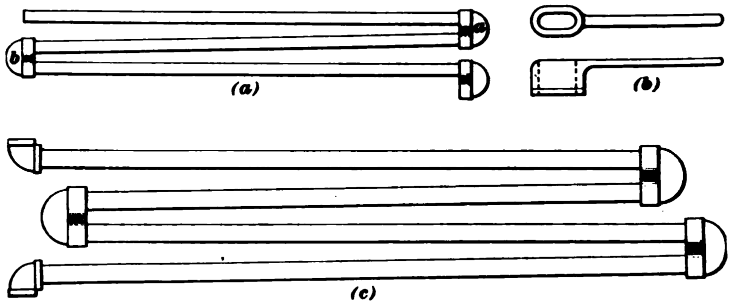


FIG. 58

cated in Fig. 58 (*c*), so that the bends will swing clear of one another when the coil is made up. Open-bend coils are constructed in the same general way, while the wide- or spread-bend coils are made with bends so pitched that the pipes run at an angle sufficiently great to allow the bends to clear one another. The various types of coils are supported by stands that are usually made to suit the different conditions to be met with on every new job.

59. In Fig. 59 (*a*) is shown a return-bend coil with a floor stand of flat ¼-inch iron 2 inches wide fastened to a cast block that supports it on the floor. This style of coil is frequently supported by hook plates fastened to the wall as well as by forged straps, which are also used to support the coil when suspended from the ceiling. Another style of coil, known as the return coil, is shown in Fig. 59 (*b*). Coils of this type are made with cast-iron manifolds *a*, *a* into which the horizontal pipes are screwed; right-and-left elbows are screwed to the pipes connected to the top manifold,

while right-hand elbows are screwed to the pipes in the lower header. The connecting pipes are threaded right-and-left, and are screwed into the elbows to complete the coil. These coils are hung on hook plates, a wooden batten or distance piece at the back keeping them from the wall. The coil shown in Fig. 59 (*c*) is designed for use on long straight

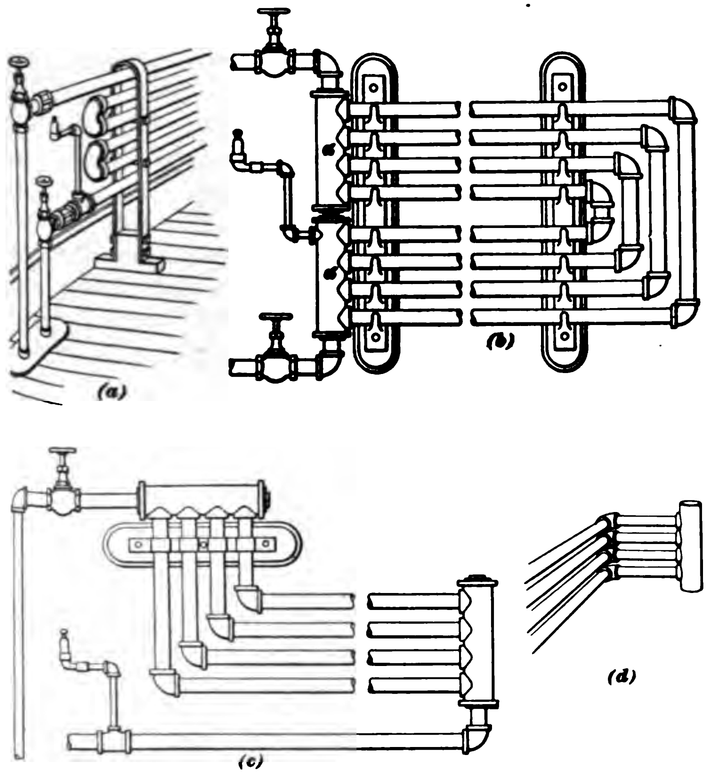


FIG. 59

walls, where it is not possible to make a horizontal right-angle turn to provide the necessary spring to take care of the expansion. The end of the coil is turned vertically upwards to make what is known as the spring piece, the length of this vertical spring piece being not less than one-twentieth the horizontal length of the coil. The spring piece

is made up with right-and-left threads, being the final connection to complete the coil. The horizontal pipes are supported by hook plates, and the vertical pipes are held in place by ring plates. The return pipe, if brought back to the supply end, is supported by single hooks to allow the pipe to be properly graded, the back end of the coil having a header or manifold in which there is one more pipe than in the supply header at the front end. In the coil shown in Fig. 59 (*d*) the spring pieces are turned at right angles horizontally, so that the coil may be used in a right-angle corner. The corner coil is supported on hook plates at points where the coil is not likely to bind, as would be the case if run around three sides of the room. If the runs are long, one end of the long run should be supported with expansion hooks, and in such cases the long pipes should be a little short of the required length, the spring pieces being sprung to meet them, so that the expansion will extend them to the required length without causing the long pipes to buckle. The final connection to such a coil is best made at the end of the long pipes by using right-and-left couplings and nipples. All coils in which the steam supply and return are at the same end should be connected up as shown in Fig. 59, in order that the valves may be accessible. The coil and valve should have a right-and-left connection, made either by using a left-hand outlet valve, or by a right-and-left coupling. The air valve should be connected by a small pipe to a **T** in the return pipe, as shown, the pipe being carried up as high as possible, so that the accumulation of air in the pipe will keep the air valve cool, and prevent the accumulation of water therein and its consequent clogging.

60. Fig. 60 illustrates a method adopted at the old printing plant of The International Textbook Company, Scranton, Pennsylvania, for securing three variations in the extent of heating surface in use, either three, six, or nine pipes being heated, as required. In the supply connection from the riser *a* are two gate valves *b* and *c* by which the supply of steam to the headers *d* and *e* is controlled. The

turn headers *f* and *g* are connected to the same sealed turn in the manner shown, the valves *h* and *i* being cessary in order to shut off either section of the coil.

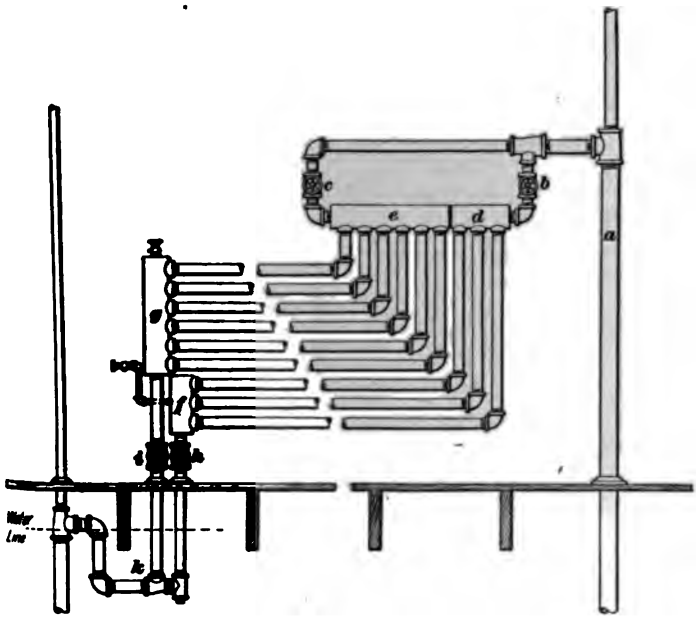


FIG. 60

The air vents are attached to the return headers. The seal of the trap formed by the piping, as shown at *k*, insures a positive and silent steam circulation.

PIPING A SMALL RESIDENCE

61. Assume that a riser, i. e., a rising pipe *a*, is to be run through two stories of a residence, in the manner indicated in Fig. 61, with a branch connection run above the floor to a radiator on the first floor, while two radiators on the second floor are supplied by branches running under the floor. The first requirement is to measure the vertical distance from the point at the cellar ceiling at which the riser is to be located to the branch for the radiator on the

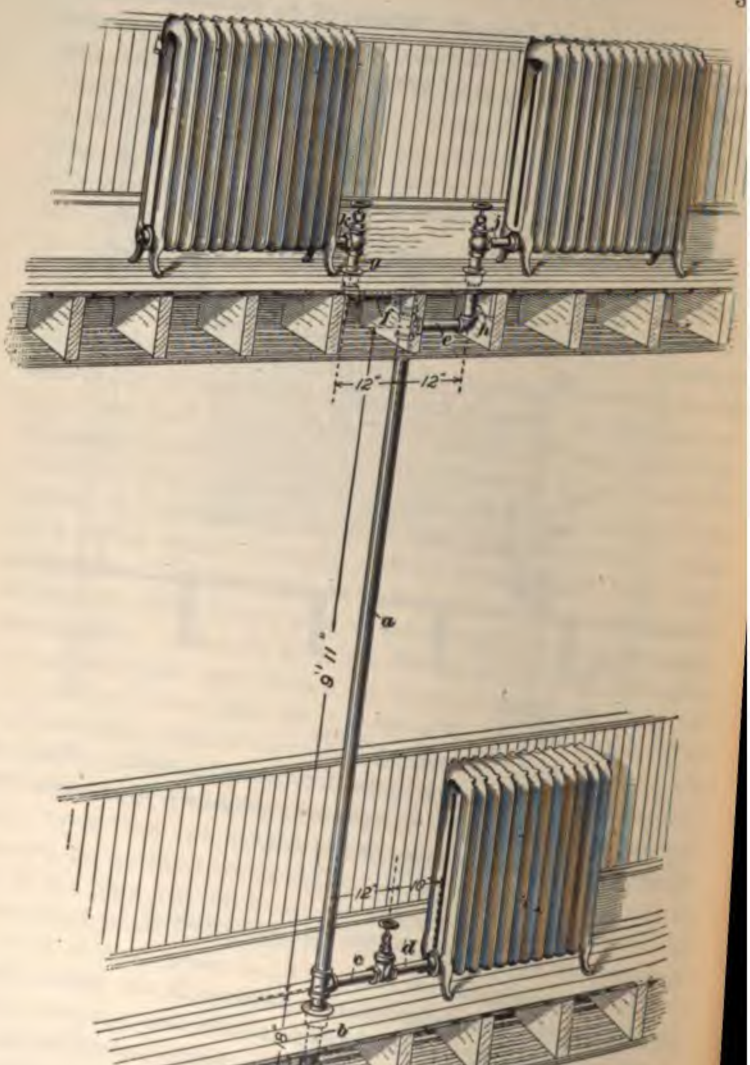


FIG. 61

floor, a note of it being made on a pad or in a book. n, the distance to a point above the first-floor ceiling, re branches to the two radiators on the second floor are e taken off, is measured, noting the fittings to be used. pipe fitter now goes to the bench, where he and his er pick out the fittings required, also getting out the ssary pipe and placing it in the vise ready to cut, having ked thereon the length required.

s much as possible of the work of making up pipes and ngs should be done at the bench. In making connections erecting the piping shown in Fig. 61, the first piece *b* to ut and threaded measures 18 inches from center of elbow enter of **T**. Between the riser *a* and the radiator valve the lower radiator, a distance of 12 inches, center to ter, is a nipple *c*, while between the valve and the iator, a distance of 10 inches, is another nipple *d*. The ces of pipe having been cut and threaded, the **T** is ewed tightly on the piece *c* while it is held in the vise. e piece *b* is now screwed into the **T** of the piece *c*, and the liator valve is screwed tightly on the free end of the ce *c*, so that its stem is pointing vertically upwards. e pipe *b*, with *c* and the valve attached, is now dropped ough the hole cut in the floor to receive it, in which a tin eve has been placed and finished on top with a floor plate. is then supported at the proper height by blocks of wood iced beneath the piece *c* near the **T**. The nipple *d*, having ight-hand thread on one end and a left-hand thread on the ier, is then made up; necessarily, either the radiator or valve must have a left-hand thread. Assuming that the liator has the left-hand thread, the right-hand threaded l of the nipple is screwed into the valve by hand, and n, placing a monkeywrench on the valve, the helper keeps rom turning while the nipple is screwed up with the tongs il fairly tight. A chalk mark is then made on the nipple, l another mark to correspond therewith is made on the ve, as illustrated in Fig. 62 (*a*) and (*b*); the nipple is v backed out of the valve, the number of turns necessary do so being counted as the mark on the nipple appears

opposite the one on the valve at each revolution of the nipple. The left-hand threaded end of the nipple *d* is now screwed into the radiator, as shown in Fig. 62 (*c*), putting about the same tension on the pipe as was done when screwing up the right-hand thread. A chalk mark having been placed on the radiator in the same relative position as the one previously made on the valve, and the nipple being correspondingly marked, the nipple is backed out, the threads, as before, being counted. Assuming that it took $5\frac{1}{2}$ turns to back the nipple out at the right-hand end and $4\frac{1}{2}$ turns to back it out of the radiator, the relative position of the mark on the nipple being the same for both ends of the nipple, there would be, therefore, a difference of one thread between the two ends. The right-hand thread, which is the longer, is screwed into the valve one-half turn, the radiator being pushed up to the nipple end, so as to bring both radiator and nipple in perfect line, and as the helper pushes up the radiator by means of a crowbar braced against the end of a plank on which he kneels, as in Fig. 63, the thread in the radiator is caught in giving the nipple the extra half turn required to make up the difference in length between the two threads. Relatively, the two threads then being practically of equal length, the nipple may be screwed up tight without fear of having a leak at either end thereof. This result is obtained only when the two ends are inserted so that the full thread of the nipple completely fills the connecting threads at each end.

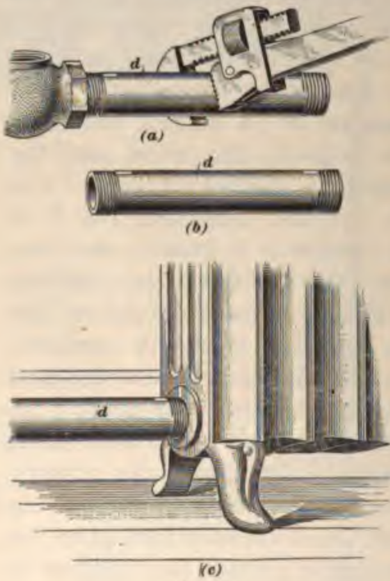


FIG. 62

The next piece of pipe *a* composing the riser measures 9 feet 11 inches from the center of the lower, or first, **T** to the center of the upper **T**, to which branches to the upper radiators connect. Allowance being made for fittings, the riser *a* is cut and threaded, the upper **T**, nipple, and elbow being screwed on at the bench. Before running the riser *a* to the second floor, a tin collar and a ceiling plate are slipped on the pipe, the **T** end being put through the hole in the ceiling, and then, while the helper steadies it, the pipe is screwed into the run of the **T** on *b*, in the manner shown by Fig. 64.

FIG. 63

Assuming that there was sufficient headroom to do so, the riser should be taken to the second floor and dropped through the sleeve in the ceiling and then made into the lower **T**, thus obviating the necessity of making a large hole in the ceiling. The Stillson or monkeywrench is used by the helper to steady the **T** and hold it rigidly while the pipe is being screwed home by means of tongs placed around the pipe about a foot above the **T**.

The branch connections to the second-floor radiators are made under the floor, and to reach the radiator on the left,

(see Fig. 61), it is necessary to cut the intervening beam. Between the two beams, near the right-hand branch, an opening is cut through the floor *a*, Fig. 65, with a carpenter's bit, and into this hole a compass saw *b* is inserted for sawing across the boards. The saw is not held perpendicularly but at an angle, so that in relaying the floor, the joint will be close. By using the floor chisel to force the boards apart after sawing them, not more than one tongue will be broken in removing the boards, and then the pipework may be done easily. With an auger and a ratchet bit, a hole *a* is bored through the beam *b*, Fig. 66, where the left-hand branch connection is to go, and in order to protect the woodwork against the danger of fire, a metal sleeve is inserted in the opening *a*. This sleeve is frequently made by cutting a strip of tin with the snips and notching it so that it can be bent over and fastened around the opening. The extent to which it is necessary to remove the flooring in order to facilitate the work of connecting up is indicated in Fig. 66, which also shows the provision that should be made for supporting the cut-out portions of the floor when relaid. A strip of wood *c*, Figs. 65 and 66, is nailed or secured by screws to the floorbeams *d*, flush with the top of the beam, the beveled joint at *e* being insufficient to properly support the floor, which is prevented from sagging and warping out of shape by being nailed to the strip *c*. The measurements from the **T** to each radiator are now taken for the pipes *e*, *f*, *g*, and *h*, Fig. 61, which are cut and threaded in the vise, at the

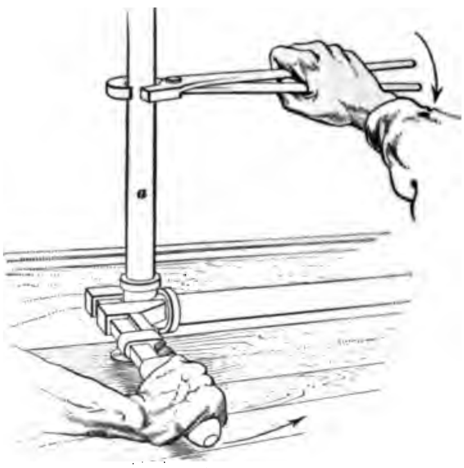


FIG. 64

bench, where elbows can be placed on *e* and *f*; the vertical connections *g* and *h* can be made by using nipples of the right length, of which a good assortment should be on hand. The nipples *j* and *k*, Fig. 61, are right-and-left nipples about 3 inches long.

The nipple *f*, Fig. 61, is passed through the opening *u*, Fig. 66, in the beam *b* and screwed into the elbow by hand, the tongs being used to make it up tight. A tin tube and floor plate are placed in the opening in the floor, and the

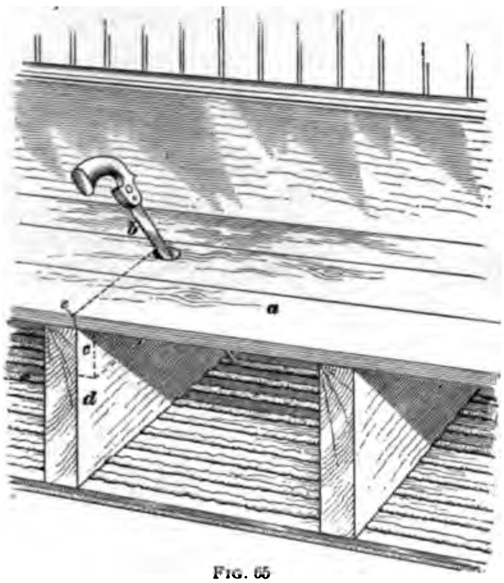


FIG. 65

nipple *g*, to which the valve is screwed at the bench, is inserted in the outlet of the elbow and made up by using a monkeywrench on the hexagon shoulder of the valve. The outlet of the valve is brought into line with the opening of the radiator, and the right-and-left nipple *k* screwed up in the same way as was done at *d*, Fig. 63. The nipple *e* is now inserted in the side outlet of the **T** on *a*, and made up with the tongs. The opening for the nipple *h* is fitted with a tin tube and floor plate, and the nipple *h* is screwed up in

the same way as the nipple *g*, and then the right-and-left nipple *j* is screwed into the radiator and valve. The floor is now replaced and fastened with nails, thus completing this part of the job.

62. In setting the radiators ready for steam, the first thing to do is to pack the valves. For this purpose, a piece of asbestos wick packing is twisted to the proper thickness, and then wet with a little oil; a few turns of the wicking are

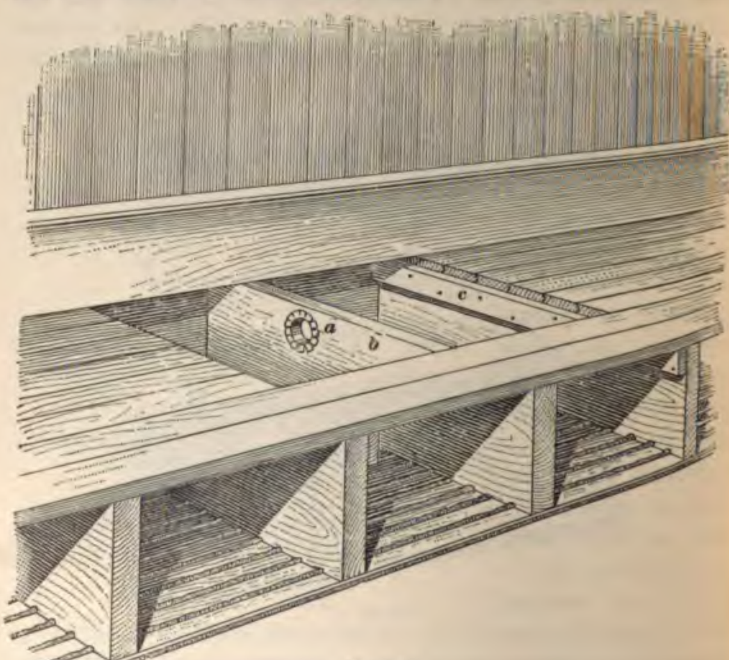


FIG. 66

wound around the valve stem, and with a knife or bent awl the packing is forced into the gland. When the cap nut is screwed up with the wrench, the packing is forced against the stem of the valve, thus preventing leakage. The air valves are now attached and the work is complete, except the connection to the main *a*, Fig. 67, which is about 10 feet away from the riser, the branch *b* being 2 feet at right angles

from the riser *c*, on the foot of which is placed an elbow. Before screwing on this elbow, a ceiling plate is slipped over the pipe and secured to it. The elbow on the riser is 4 inches from the ceiling, while the main is 12 inches below the ceiling, and as the branch is a long one and has no relief pipe, it is given a pitch, or downward inclination, of 2 inches. Having determined these measurements, the pipe is cut and the fittings assembled, the latter consisting of two elbows, one nipple *d* to make up 6 inches, and a nipple and right-and-left coupling to make the final connection. The nipple *d* is screwed into the outlet of the **T** on the main *a*, and to this nipple is connected an elbow *e*, the **T** and all connections being made up together to save time, the threads, of course, being clean and properly lubricated. With the brace and bit, a hole is bored in the ceiling for the lag-screw of a pipe hanger through which the pipe is passed, the elbow on the end having been screwed on

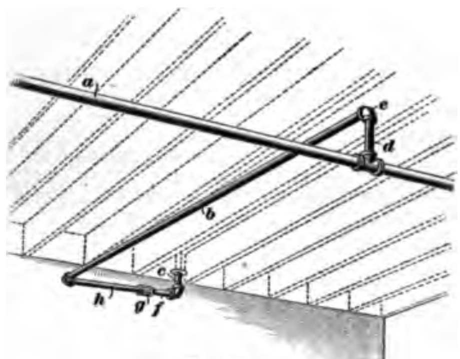


FIG. 67

in the vise. The branch *b* is then screwed into the elbow on the nipple at the main, and made up tight with the Stillson wrench or tongs. The branch *b* is then so adjusted that the elbow on the end thereof is in line with the elbow on the riser. The short length of pipe *h* is then inserted at the elbow at the end of the branch and screwed up; then the right-and-left nipple *f*, with the right thread in the elbow on the riser, is screwed up and made tight. On prying the pipe sections *h* and *f* apart, the right-and-left coupling *g* can be inserted. Screwing up this coupling with pipe tongs makes the final connection between the main and the radiators and completes the job.

PIPE-FITTING PRACTICE

(PART 2)

ARRANGEMENT OF PIPING

SUPERINTENDENCE OF WORK

TOOLS AND MATERIALS

1. Introduction.—When a pipe fitter is sent out to take charge of work at a considerable distance from the shop, he is generally made the foreman of the men on that job, and his employers expect him to see that the work is done promptly and in a neat, workmanlike manner, without waste of time in unnecessary elaboration with fittings. He receives the instructions of the firm, or of the firm's superintendent, and it is his duty to see that the men with him work faithfully and perform satisfactory work. Some shops do not allow higher wages for this important position, while others do; or, the man in charge is allowed to do extra work after working hours, for which overtime he is paid double. Some firms give a bonus when the job is completed, provided that it is done within the time estimated.

2. Accounting for Tools.—When about to be sent to the work, the pipe fitter is usually given a list of the tools provided for and charged to him, a duplicate of which is checked off and signed by him, and for which he must render an account when the job is completed. Lost tools must generally be paid for by him unless satisfactory explanation

is made as to the cause of their loss; broken or damaged tools are usually returned to the home shop for repairs, with an explanatory note or letter of instructions.

3. Care and Storage of Materials.—In order that materials may be readily found when wanted by the workmen, the pipe fitter in charge of the job is expected to make special provision, by bins and boxes, for the care of fittings, and see to it that in cutting up the pipe the ends of all short pieces are properly threaded, so that such short pieces of pipe may be utilized whenever possible. When they arrive at the work, the various materials, such as piping, fittings, valves, etc., are deposited in convenient positions on the floor, the different sizes of pipe being laid out in separate banks, with sticks between to keep them separated. The fittings are turned out of the boxes in which they may have been sent from the shop and are placed in their respective bins of the fitting box, which are properly marked; thus, the T's are arranged according to size, then the reducing T's in the same order, then the T's that reduce on the run, then the elbows in their class and so on. If a fitting box is not available, the fittings are laid out on the floor, blocks of wood serving to keep them from getting mixed. Valves and other costly accessories are usually kept locked up either in the tool box or in some closet.

A good workman keeps his tools within easy reach of the work he is doing, in order to avoid waste of time and energy in traveling to and from the tool chest. When his day's work is done he returns all tools, properly oiled to prevent rust.

4. Special Instructions.—Extreme care in following plans and specifications is especially approved. When in doubt as to the requirements of the latter, the pipe fitter is expected to get special instructions from the home shop, to which all orders for material should be forwarded a few days before it will actually be required for the work.

SHARP, BRIGHT & CO., Incorptd.

Daily Time Card

Shop Order No.______________________ Month______________________ 190___

For______________________ Day______________________ Date______

HOURS Regular	HOURS Overtime	GIVE BELOW FULL DETAIL OF WORK. STATE NO. RISER AND NO. OF PIECES OF PIPE RUN IN EACH; IF RADIATOR BRANCHES, GIVE NO. OF RADIATOR AND NO. OF BRANCHES RUN; ALSO DETAIL OF OTHER WORK AND AMOUNT DONE. STATE TIME SPENT ON EACH. MAIL CARDS EACH DAY.

Approved______________________ Name______________________

RECORDS

5. Time and Material Records.—The pipe fitter in charge of the work is generally required to keep an account of all the time, and of materials used on orders for extra work, i. e., on all work other than that called for by the specifications. The blanks provided for such records, which include memoranda as to the exact nature of the work, are usually signed by the owner of the building or his authorized agent. An account of all time on the regular contract work is also kept, a record of each day's work being kept on *time cards*, similar to the one shown, which are provided for that purpose, all expenses being itemized, charged to, and subject to revision, by the firm. Each workman on the job is given time cards, on which is made his daily report of the time spent on the different parts of the work that he does, and these cards indicate the number of hours for which he is entitled to draw his wages. These cards also serve as checks in any dispute between the employer and the owner of the building or the latter's agent, the time and material given on the cards having been certified as correct by the owner or agent at the time the work was executed. When the workman's report involves materials as well as time, the materials used on the job should be specified on the back of the card, in order that correct charges may be made. For future reference, the workman should also keep a record of the work done by himself, for his ambition may lead him to become an employer some day; or he may rise to the position of foreman, in which case he should know how much work should be done in a given time; also what amount of time to allow for different operations when called on to make an estimate.

6. Ordering Materials.—In ordering materials, the workman should use a printed form book, the form being similar to that shown. Beneath each printed leaf there should be a blank leaf, a piece of carbon paper being placed under the printed leaf, with the carbon side next to the blank

WORKMAN'S MATERIAL ORDER BLANK

Shop Order No.__________ Date____________________

To SHIPHAM, QUICK & CO.

Please deliver to (Job)______________________________

List of Material as follows:

WORKMAN'S SKETCHING PAD

*JOB NO.*________________ *DATE*________________________

*LOCATION*______________ *SKETCH FOR*____________________

Make all sketches in triplicate, two of the copies to be forwarded to the office and the other one to be kept on the job. Be particular to give fully the size of pipe and outlets, and to state whether fittings and valves are to be screwed or flanged.

leaf, so that in making the original order a copy is also made and kept in the book, while the original order is sent to the shop.

7. Sketches.—A ruled sketching pad having data printed at the top of each sheet similar to those on the sample shown herewith, may be used advantageously for sketches of piping and special work. It is advisable in using the sketching pad to insert a sheet of carbon copying paper beneath the sheet being sketched on and also beneath the sheet below, in order to obtain two carbon copies of the sketch. One of these carbon copies is then kept by the man on the job, while the other is sent to the pipe cutter, blacksmith, or other workman for the special work needed, the original being kept in the office. The sizes and all dimensions should be marked plainly on all plans or sketches so as to obviate all possibility of dispute.

ERECTION OF A SMALL STEAM-HEATING PLANT

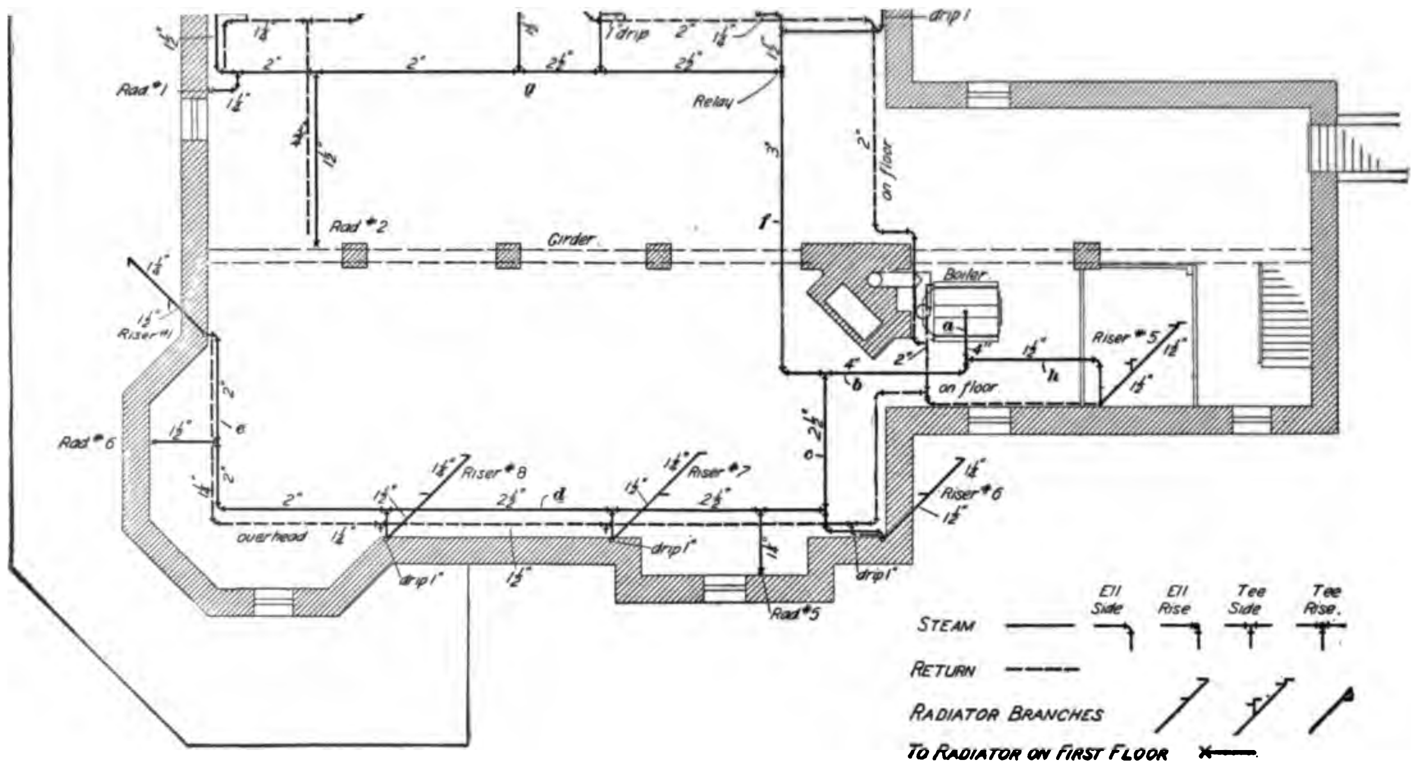
PRELIMINARY EXAMINATIONS

8. On arriving at the job, the first work is to set up the bench, the location of which should be as central as possible with reference to the work to be done, with plenty of space at the ends of the bench to facilitate the handling of long pipe. Having located the space for the bench near the center of the work, the tool box is placed near by, and out of it are taken such of the larger tools as are frequently needed, arranging them on the floor, but leaving the small tools in the trays of the tool box. The materials having been arranged, that part of the building in which the work is to be done is examined, peculiar obstructions, if any, to the running of vertical piping are noted, and investigation is made as to the best way to get around them. Then, in order to locate the beams, the workman takes the search gimlet and hammer, and, by means of the latter, sounds the floor that he proposes to cut. He measures the distance to the nearest wall that is plumb with the wall below, and then on

the floor below he sounds for beams at a similar distance from the wall. Having located them and found the way clear, the point for beginning operations is marked. With the search gimlet a small hole is bored through the ceiling from above, while a helper in the room beneath watches to give warning before the gimlet cuts too large a hole in the plaster work. Having this mark for a guide, the helper gets a ladder and holds the line of the plumb-bob at the mark left by the gimlet on the ceiling, so as to get the center of the hole to be drilled through the lower floor. These operations are continued in the same way until the line of holes is carried straight through as far as it is necessary to go. The space to be occupied by the radiators is measured and allowance made for connections. Having determined these correctly, the pipe fitter instructs the helper to bore the required holes with the brace and bit. If the pipe connection is small, the extension bit may be used for making the holes, but, if large holes are required, small holes are first bored, and then the compass saw is used to complete them, and after all the necessary openings for the piping have been cut, the lengths of the pipes to be run are marked off.

LAYING OUT AND ERECTION

9. Designations.—For the purpose of illustrating the methods generally followed by pipe fitters in laying out an ordinary piping system, the basement plan of a residence is presented in Fig. 1, which shows the location of the apparatus and piping of a heating job having single risers and radiator connections and relief pipes, or drips, connecting the foot of each riser with the return main, to which drips from the steam main are also connected at convenient points. It will, of course, be understood that equally good results could be secured by piping the building in other ways, but the illustration given will serve the purpose of showing how different portions of the work may be designated by numbers in such a way that the fitter at a considerable distance from the shop may, if necessary, write for information or instructions,



Rad. #1
Rad #2
Girder
Relay
Boiler
on floor
Riser #1
Riser #5
Riser #6
Riser #7
Riser #8
Rad #5
Rad #6
drip 1"
overhead
STEAM
RETURN
RADIATOR BRANCHES
TO RADIATOR ON FIRST FLOOR
Ell Side
Ell Rise
Tee Side
Tee Rise.

FIG. 1

giving a more intelligible description of difficulties encountered than would, for instance, be possible, if he had to refer to, say, the front riser, which, in this case, might be either of risers Nos. *1* and *2*. By numbering each riser and radiator, questions addressed to the home office may intelligently be answered, thereby obviating the possibility of getting, as well as avoiding the delay due to following, misleading instructions. Furthermore, the system of numbering permits of keeping a satisfactory record of the work being done by the men on the job.

10. Measurements.—The first measurements to be taken are for the supply main, the first length of which is 4 inches in diameter. The starting point is found by plumbing down with a plumb-line to the center of the outlet on the boiler; the distance from the starting point to the first T, at which a $1\frac{1}{2}$-inch branch is taken off, that is, the length of the pipe line *a*, is found to be 2 feet 8 inches, the measurements being transferred to a sketch, as in Fig. 2, which is a drawing of the pipe and fittings on which the lengths can be marked for reference. In order to make easier the reading of this sketch in conjunction with the plan given in Fig. 1, corresponding pipe lines have been given the same reference letters in Figs. 1 and 2.

The next measurement is from the T to an elbow, a distance of 12 inches; then the distance from the elbow to a $4'' \times 3'' \times 2\frac{1}{2}''$ T is found to be 7 feet 8 inches. The exact location of the center of the last-named T must be determined in order to fix a point from which other measurements may be correctly taken. To do this the pipe fitter takes a steel square and lays off the center line of the piping *b*. From the outlet of the second T, at right angles to the second line of pipe *b*, the distance to the next fitting, a $2\frac{1}{2}'' \times 1\frac{1}{2}'' \times 2\frac{1}{2}''$ T, is measured and found to be 6 feet 8 inches. The branch pipe from the last-mentioned T can be measured later. Continuing from the side outlet of the T, the measurements to the various fittings are as follows: 3 feet 4 inches to the next $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 1\frac{1}{4}''$ T; 7 feet 8 inches to the $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 1\frac{1}{2}''$ T;

et 4 inches to the $2\frac{1}{2}'' \times 2'' \times 1\frac{1}{2}''$ T; then, 9 feet to the h elbow; 3 feet 6 inches at right angles to the $2'' \times 2''$ $''$ T, and finally, 5 feet to the 2-inch elbow at the end of ine *e*. At each point where one of the fittings named is to cated the ceiling is marked to indicate where the center

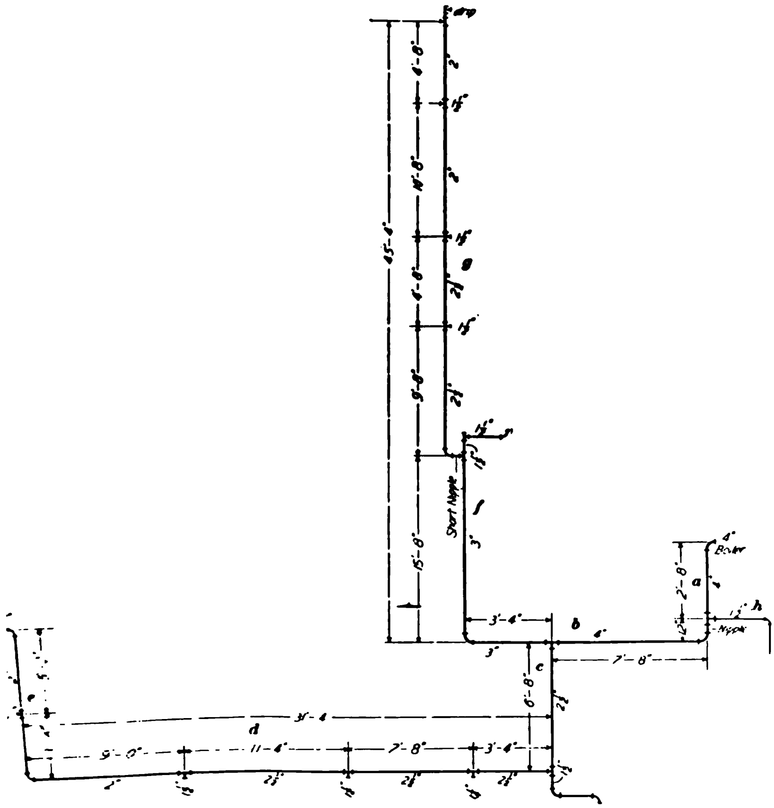


FIG. 2

of each fitting is to come, as a future guide in erecting the piping. Starting at the 3-inch outlet of the $4'' \times 3'' \times 2\frac{1}{2}''$ T on the pipe line *b*, the measurements for the second branch of the main line are as follows: 3 feet 4 inches to the 3-inch elbow; 15 feet 8 inches, at right angles, to the $3'' \times 1\frac{1}{2}'' \times 2\frac{1}{2}''$ T, where it is advisable to rise by a short nipple to

allow more headroom, the branch to riser No. *4* being measured after the measurements for the mains are made. Proceeding, it is found to be 9 feet 8 inches to the next $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 1\frac{1}{4}''$ **T**; 4 feet 8 inches to the $2\frac{1}{2}'' \times 2'' \times 1\frac{1}{4}''$ **T**; 10 feet 8 inches to the $2'' \times 2'' \times 1\frac{1}{4}''$ **T**, and 4 feet 8 inches to another **T** where, with a nipple and an additional **T**, provision is made for the drip connection. This finishes the measuring of the main.

11. Erection.—As large pipe can be cut to better advantage by machine, the piping measured for may be cut in the shop to save labor on the job. The centers of the fittings on the main having been located and properly marked, the branches may be cut on the job while waiting for the main to arrive. When the main, cut to measurement, is received at the job, it is immediately laid out on the floor, according to the sketch previously made, and measured to see that the various lengths of pipe correspond with the required dimensions, the fittings and pipe being assembled so as to allow for the length of the threads. Having found the piping to be correct in measurement, the next step is to stretch cords between marked points to represent the center lines of the pipe lines for locating the position of pipe hangers, which are then put up and approximately graded; everything is then in readiness for the erection of the main. Part of the latter (the line *a*, Figs. 1 and 2) can be made up on the floor to better advantage than at the ceiling, so the 4-inch elbow and the $4'' \times 4'' \times 1\frac{1}{2}''$ **T** are screwed on, and then the short piece or nipple and the next elbow, the whole being screwed up tight with the chain tongs while on the floor. The pipe is then raised to the ceiling and supported in the hangers. On the next length of piping *b* the **T** and the short pipe and elbow are made up tight and the pipe hung in the hangers, which are then temporarily reenforced by rope or trusses of wood while the pipe is being screwed into the outlet of the elbow on the section *a* previously erected. The remaining sections are made up in the same manner, the pipe fitter always seeking to do the work to the best advantage in

the easiest, most direct, and most effective way. After the main is erected, the pipe is properly graded or pitched toward some point at which the condensation may be conveniently drained.

12. The grading and draining of the mains are important, especially as the reduction in the size of the main has a tendency to facilitate an accumulation of the water of condensation, which is quickly removed by providing a drip pipe through which it is drained to the return main. Furthermore, in order that the steam which passes from the mains to the radiators may be as free from moisture as possible, the branches are usually taken from the top of the main, although the branch from the main to the riser is sometimes taken from the bottom of the supply main, and drained into the return main. This method may be applied to relieve the main at points where reductions are made, or separate drip pipes may be taken from individual fittings.

In erecting the main at the boiler, the elbow directly over the boiler is brought into proper alinement, and in it is placed a nipple, to which is screwed a flange union. The final measurement, or the distance between this flange and the boiler outlet, is then taken, allowance being made for the threads in the boiler outlet and in the lower half of the flange union, which should be screwed up tight to the connecting pipe before the latter is screwed into the boiler outlet. From the boiler, the piping drains toward the fitting that connects riser No. *5*, where a drip or relief pipe serves to drain both the main and riser. The **T** in the branch at riser No. *5* is turned downwards, the run of the **T** being at an angle of 45° with the axis of the branch, nipples and 45° elbows being used in making the riser and drip-pipe connections. The branch connection to riser No. *7* is taken from the top of the main. In making connections to riser No. *6*, the pipe is taken from the run of the **T** on the supply main, expansion being provided for by using two elbows on the branch pipe. The branch to radiator No. *5* is taken from the top of the main, the final connection being made at the

radiator. The branch to riser No. *8* is taken from the bottom of the main, the expansion of which is calculated to be about $\frac{22}{100}$ inch, with a full 90° elbow. The main being reduced at this point, the bottom connection serves to relieve the main of condensation, the branch connection in other respects being similar to those previously described. From this point the main connects to an elbow, thence to the next $2'' \times 2'' \times 1\frac{1}{2}''$ **T**, from which a branch is taken from the top of the main to the riser of radiator No. *6*. At the end of the pipe line *e* is a 2-inch elbow, the branch from which is carried full size to the foot of riser No. *1*, where a $1\frac{1}{4}$-inch drip connection is provided.

13. The return main for the branches on the pipe lines *d* and *e* is carried overhead, alongside of or directly beneath the steam pipe; it is therefore called a dry return. The connections to the return main from the foot of the risers are made above the water-line, and hence the pipe should be ample in size, in order that the water of condensation from the risers will not fill the pipes. The return main has a downward pitch toward the corner at riser No. *6*, where it drops below the boiler water-line, so that it will drain rapidly. The steam main, with the relief pipes at the foot of the risers draining the condensation from it, can be run nearly level; the drip branches from the risers should drain into the return main at the top.

The supply main *f* for the other side of the building drains to the $3'' \times 1\frac{1}{2}'' \times 2\frac{1}{2}''$ **T**. As this main passes under a girder, it will have a large pitch and will be drained through the $1\frac{1}{2}$-inch run of the **T** without taking a separate drip therefrom. If it were necessary to keep the main up nearly level, it would be better to take a separate relief pipe from a $3'' \times 1\frac{1}{2}'' \times 1''$ **T** placed in the line just beyond the $3'' \times 1\frac{1}{2}'' \times 2\frac{1}{2}''$ **T**. It would then be necessary to substitute a $3'' \times 3'' \times 2\frac{1}{2}''$ **T** for the fitting just mentioned. Another method would be to extend the 3-inch pipe as far as the branch to riser No. *4*, the drip being taken from it at that point, the riser connection being similar to those already described. From the

$3'' \times 1\frac{1}{2}'' \times 2\frac{1}{2}''$ T the main, with a nipple and elbow, rises with a relay to allow more headroom, and from the elbow the main *g* pitches downwards. Where the branch to radiator No. *3* is taken off from the bottom of the main, the latter is reduced to 2 inches, the branch and riser connections being the same as those described in connection with riser No. *8*. The branch to riser No. *3* is taken from the top of the main, the condensation flowing back into the return through a 1-inch drip at the foot of the riser. The next branch, to radiator No. *2*, is taken from the top of the main and pitched

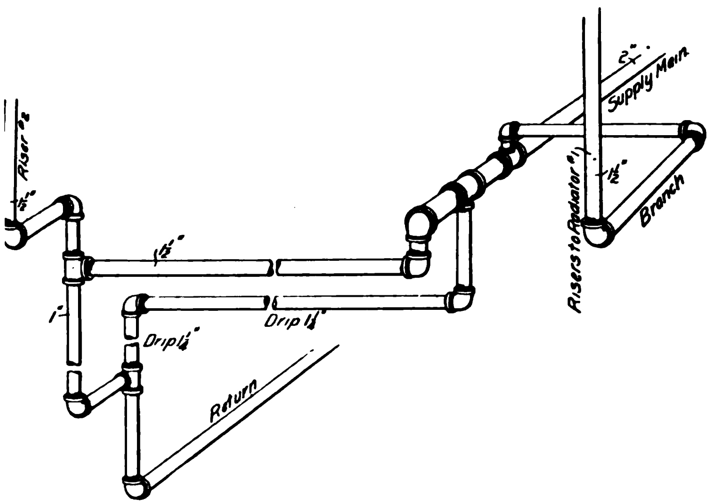


Fig. 3

wnwards from the main to the end of the branch, where a parate $\frac{3}{4}$-inch drip connection is made at the foot of the er, the return branch being carried along near the ceiling the side wall, where it drops into a wet return and is reby sealed. The main is continued full size to the inch to radiator No. *1*, and thence to a separate relief-pipe inection made before the main branch connection to riser . *2* is taken off by the $2'' \times 1\frac{1}{2}''$ elbow. The connections the riser of radiator No. *1* and riser No. *2* are made with ows, in the manner indicated in Fig. 3, to allow for the ust of the pipe due to expansion, which the elbows permit,

forming a kind of hinge joint. The drip pipes from the risers on this side of the building are carried on the side wall, so that there will be plenty of headroom; they are below the water-line of the boiler, and are therefore sealed returns.

14. The return main on the side wall may be supported by hooks driven into the wall, or by expansion hangers, which are preferable. From riser No. *4*, the return main may be carried along the floor, or under it; but if the pipe is run under the floor, a trench should be provided, so that it will be accessible, as pipe in the ground soon rusts out. The two return mains are connected together into one pipe, and then to the boiler, where provision for draining the entire system should be made. If the return connection to the boiler is made at a point above the level of the floor the return connection is made by using a **T**, in one of the runs of which is placed a draw-off cock, which will also serve for draining the boiler; but, in cases where the boiler is lower than the return main, the draw-off cock would of necessity be placed in the boiler.

The boiler shown on the plan given in Fig. 1 is a common type of sectional cast-iron boiler. The return connections are made to two return drums, one at each side of the boiler. In cases where the steam main is not well above the water-line of the boiler, it is advisable, merely as a matter of protection, to place a check-valve in the main return pipe near the boiler, in order to prevent the water therein from being forced back into the return main. When steam is first turned on, the condensation of steam in the radiators is very rapid, and in case the steam main is not sufficiently large, or partly closed, the pressure in the radiators will be lower than that in the boiler; hence, the boiler pressure tends to back the boiler water up the returns and into the radiators. When a portion of a heating system is sealed under the conditions indicated, or from any other cause, a disagreeable pounding noise, commonly called water hammer, frequently results when the steam attempts to force its way to the radiators or piping beyond the sealed point. When a check-valve is used

in the main return, the water accumulates in the return pipes until the hydrostatic pressure exerted by the water is greater than the difference between the boiler pressure and the radiator pressure, when the water flows into the boiler by gravity, establishing a continuous uniform circulation throughout the system.

15. **Trimming the Boiler.**—The boiler is delivered at the job in sections and is erected by the pipe fitter in the position assigned for it. The boiler, if of the vertical slab type in common use, consists of base sections, grates, ash-pit door and frame, front section, intermediate sections, fire-back or bridge-wall section, rear section, and steam and water drums; the accessories to the boiler are the fire-doors, the flue doors, the rear check-draft doors, and the trimmings. In erecting and trimming the boiler, the first operation is to put in a substantial foundation of brick laid in cement on which the cast-iron base of the boiler should rest in a perfectly level position. After placing the grates in the base section, the front section is erected and then an intermediate section is laid flat on the base section so that asbestos wick, soaked in a mixture of red and white lead and linseed oil, may be used to fill the groove that serves to make the joint between the sections. A good packing paste for use between the sections may be made by taking equal parts of red and white lead and mixing them together in boiled linseed oil, with a little loose asbestos. This mixture can be rolled out into a rope-like form and can then be placed between the sections of cast-iron boilers, so that when the sections are brought together, the packing is forced into the recesses therein, filling them completely. Having filled the groove, the section is raised and pressed into position, the other intermediate sections being erected in the same way. The bridge-wall section is then put in place, and lastly the end or smoke-chamber section, when the sections are ready for connection to the drums. In order that the centers of the tappings at the base of the sections may correspond with the centers of the openings in the drums, the sections are brought into

proper position by using a clamp consisting of two planks, one at each end of the boiler, a loop of rope around each end of the planks being twisted with a piece of wood as a lever until the required tension on either or both sides of the boiler is secured. The headers are then fitted with the locknut nipples, the first and last ones being screwed into the sections to get the header in line, when the other nipples may be made up. After the nipples are tightly screwed into the sections, the locknuts are backed on the thread and a turn or two of asbestos wick soaked in oil and lead is wrapped around the thread as close to the drum as possible; the locknut is then forced up on this packing, and the joints are thus made tight. After the drums are connected, the clean-out doors are placed in position, the smoke connection bolted on, the flue doors and the fire-door frame fastened to the front with bolts, and then the various trimmings are connected.

16. In attaching the water-gauge combination column, the height of the water-line in the gauge glass is fixed by so placing the column that the middle thereof will come opposite a point 2 inches above the top of the flues; thus there will be water over the flue space of the boiler when the water half fills the gauge glass. The top of the water column should be connected to the top of the steam drum, and the lower end to the return header. The damper regulator is then attached, and its lever is so adjusted that the chain on the front end opens the draft door at the same time that the chain on the rear allows the check-draft door to fall; these chains may be connected direct or over pulleys, as may be required.

The safety valve is then connected to the top of the steam drum. If a spring safety valve is used, it may be adjusted, by comparison with the steam gauge when the boiler is under steam, for the pressure required by means of a nut on the valve stem through the turning of which more or less tension on the spring may be secured. If a lever safety valve is used, it may be adjusted to secure

e desired pressure of steam by shifting the weight on the ver to the required position as marked on the lever. The eam gauge is then connected up and may be attached to T on top of the combination column, using a siphon to prevent steam from entering the gauge. The gauge-cocks are crewed into the openings in the water column, to which the water-gauge glass is then attached. A draw-off cock may be screwed into a T at the bottom of the water-column stand pipe, or, when the return pipe is below the return header, the draw-off cock may be placed in the return connection.

Boilers of the vertical-slab type have the water-line so close to the steam drum that entrained water is frequently carried into the steam drum with the steam, and it is therefore a wise precaution to provide an equalizing pipe, which serves chiefly as a drip pipe for draining condensation and entrained water from the steam drum to the return drums. The smoke pipe at the rear of the boiler is now connected with the chimney flue.

The position in which the automatic water feeder is placed, if one is fitted, should be such as to bring the water-line of the feeder at a point 2 inches above the top of the upper flues. Having located the feeder at the proper height, it is connected up by $\frac{3}{4}$-inch pipes to the steam and return headers. The feedwater tapping is then connected by a $\frac{1}{2}$-inch or a $\frac{3}{4}$-inch galvanized-iron pipe to the water-supply pipe, not omitting the necessary cocks and check-valves. In arranging the connections, a by-pass in the water supply to the feeder should be provided for use in feeding the boiler direct in case of necessity, as when repairs are required.

The plumber usually makes the water-service connection to the boiler, placing in line a supply cock having a lever handle or a square head and a mark or other indicating device by which it can readily be seen whether the water is turned on or off.

17. Having turned on the water, which rises in the boiler to the level for which the automatic water feeder is set, the boiler is ready for steam. A fire is started, and as steam is

raised to a fairly high test pressure, an examination for the location of flaws and leaks throughout the entire system is made. As many of the leaky joints as possible, if any, are tightened while the steam is on the system, and those that must be taken care of after the steam pressure goes down are marked with chalk, so that they will not be forgotten. These leaks should be repaired immediately and the piping system again tested; if tight, the damper regulator should be adjusted by shifting the weights on the lever, so that the ash-pit door will close and the check-draft door at the back will open when the pressure reaches a point a little above that required to do the heating. The apparatus is then ready for the householder to use, but before leaving the job, the pipe fitter sees that all air valves are adjusted and that all radiators are circulating properly.

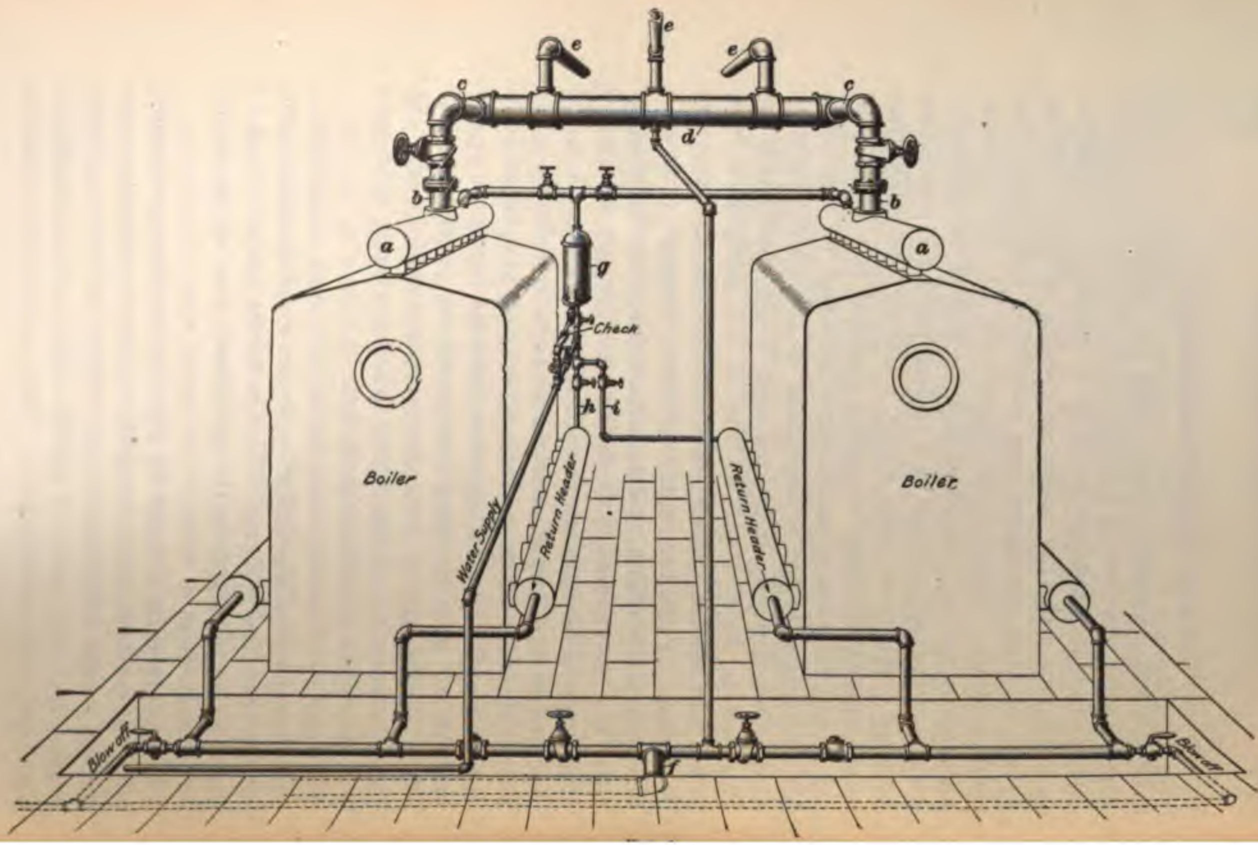
18. Finishing Touches.—The bronzing of the radiators and risers in the rooms may be done by a painter or by the pipe fitter's helper, as required. The body paint may be yellow ocher mixed with boiled linseed oil. All exposed parts are painted with this mixture, which is baked on while the pipes are hot, and when dry, after the radiators are cool, the bronze is mixed with the bronzing liquid and the radiator surfaces smoothly coated therewith, the bronze being fixed so that it will not easily rub off, by a coat of copal varnish. All the iron around the boiler should be painted with a good coat of black enamel, and if the pipes are not to be covered, they also should be similarly painted. The pipes, however, ought to be covered with some form of non-conducting covering to increase the heating capacity of the boiler and save fuel. The boiler and smokestack should be covered with a covering of wire netting so applied as to provide air space between the boiler or smoke pipe and the covering, which may be a cement of asbestos or magnesia put on about 1 inch thick, and roughed like plaster on a wall; a fine coat is then put on, smoothed with a trowel, and painted to make a neat finish.

TWIN BOILER CONNECTIONS

19. When extensions are made to buildings already equipped with satisfactory heating apparatus it is sometimes desirable to install another boiler to be connected to, and run in conjunction with, the boiler and piping already in place, without making necessary any extensive changes in the piping system. Under some conditions, as, for instance, when only a part of a building is to be heated continuously, it is also desirable to install two boilers instead of one in new buildings. Wherever and under whatever conditions two boilers are connected up to operate together as a single unit, care should be taken to make ample provision for expansion and contraction in the arrangement of the piping between them. Two methods of making twin boiler connections are illustrated in Figs. 4 and 5. Fig. 4 is a perspective rear view of two boilers, showing the return as well as the supply connections. From the supply outlets in the steam drums *a*, *a* rise the lines *b*, *b*, which, as shown, have flange unions and gate valves, the loop branches *c*, *c* to the steam supply manifold *d* being screwed into elbows on the ends of the pipes *b*, *b*, and connected to the supply manifold by reducing elbows. The steam mains *e*, *e*, which are inclined toward, and hence drain to, the foot of the risers, are taken from the top of the supply manifold, to give as much headroom as possible in the cellar. Condensation from the supply manifold and the piping between it and the boiler drains back into the return main through a drip pipe, as shown.

The pipes *b*, *b* and *c*, *c* must be large enough to allow this, otherwise the manifold will not act as a good pressure equalizer between the boilers. The size of the pipes *b*, *b* and *c*, *c* should each be equal to the combined area of the steam mains taken from *d*.

The return main *f*, which in this case is shown as running below the cellar floor, is connected to the return header manifold by means of a nipple and elbow, the former being screwed into the outlet of a **T** at either side of which are placed gate and check-valves. The gate valves are used in



e
e
e
c
c
d
b
b
a
a
g
Check
h
i
Boiler
Boiler
Water Supply
Return Header
Return Header
Blow off
Blow off
f

cutting either boiler out of service, the corresponding steam-supply valve having been closed, while the check-valves serve to prevent such fluctuations in the water level of the boilers as might be due to uneven firing. The water lost through the escape of vapor at air valves, etc. is supplied automatically by a water feeder *g*, which maintains the water in both boilers at the same level, the feeder being by-passed for direct feeding to either or both boilers, while pipes *h* and *i*, having valves and connected to the two inside

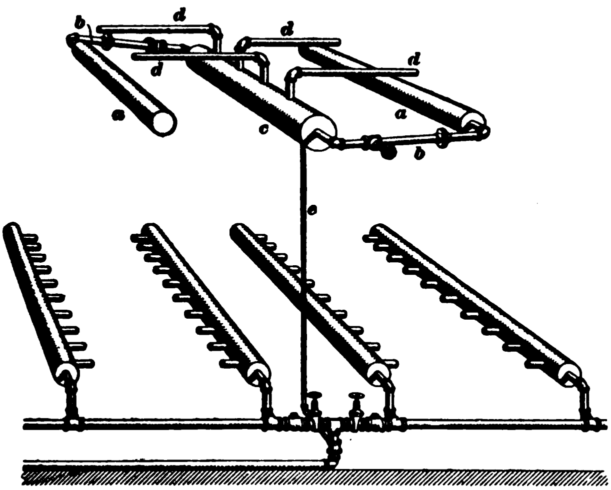


FIG. 5

water drums, that is, return headers, permit the feedwater service to either boiler to be shut off.

20. Where the available headroom is limited, the boilers may be connected up as indicated by Fig. 5, which shows how the steam-supply manifold may, if necessary, be carried a little below the level of the steam drums *a*, *a*, to which it is connected at opposite ends, to make ample provision against injurious stresses due to expansion or contraction. The branch connections *b*, *b* to the supply manifold *c* are made up as shown. A drip pipe *e* is connected to relieve the supply manifold *c* of water of condensation. The supply

lines *d*, *d* may, if necessary, be arranged so as to just clear the steam drums, rising from the top of the steam-supply manifold only enough to give the requisite pitch to the mains toward the foot of the risers or to other points where drip pipes are attached.

The arrangement of the return and feedpiping with the method just described for connecting up the supply piping in basements having low ceilings would be the same as that shown in Fig. 4. The pipes *b*, *b* and header *c* must be large enough to equalize pressures and maintain steady water-lines. The check-valves used must be swing checks, so that they will open readily. When independent equalizing pipes are used in connecting up two or more boilers, the steam connection should be about one-half the capacity of the main steam pipe, while the water connection should be from one-quarter to one-half the capacity of the main return pipe.

21. Unequal water-lines in twin boilers, that is, failure of the water to be at the same level in both boilers while steaming, are quite common where the steam-header connections are too small. This difficulty, however, may be remedied by enlarging the equalizing steam pipe, thus securing practically the same pressure in each boiler. A study of Fig. 6 should show how pressure varies in different parts of the apparatus under different conditions. In Fig. 6 (*a*) is shown a diagrammatic view of two boilers connected up with a steam manifold above and a return manifold below. The steam main connects to the steam manifold, and its corresponding return main to the return manifold. If the valves *a* and *b* are closed and the others open, the pressure in one boiler will be exactly the same as that in the other, because the steam manifold acts as an equalizing pipe. This being so, the water-line in one boiler will be exactly level with that in the other, as shown, no matter what pressure is carried by the boilers. If, however, the pressure in one boiler becomes less than that in the other, water will be forced from the boiler having the higher pressure, thereby raising the water-line in one and lowering

it in the other until the difference in the water levels represents a hydrostatic head great enough to balance the difference in pressure between the boilers.

So long as the boilers are fired the same and the resistance to the flow of steam from each boiler to the steam manifold is the same, the resultant pressures will be practically the same in both boilers and the water-lines will be level. But, if one boiler is more heavily fired than the other, and if the steam connections are small, there may be a decided difference in the steam pressure in the boilers, and a consequent difference in the level of the water-lines.

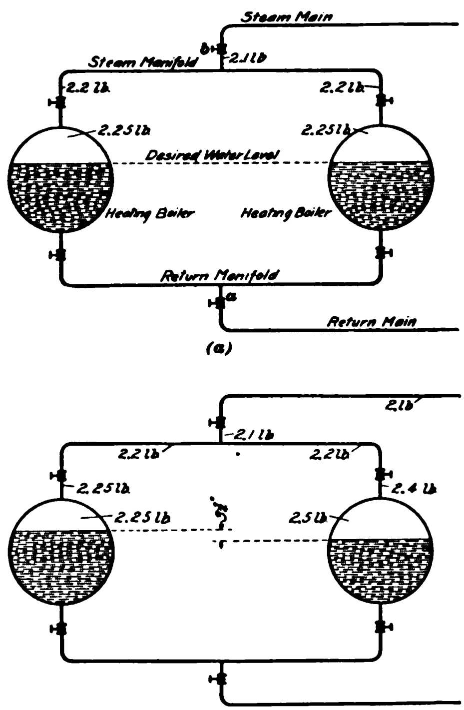


FIG. 6

In Fig. 6 (*a*), the steam manifold and its connections are very large, and a practically equal pressure of 2.25 pounds is held in each boiler even though one boiler may be doing nearly all the work. This result is obtained only when the steam connections are very large. When they are of ordinary size, a difference in levels of water-line is frequently noted, as shown in Fig. 6 (*b*), wherein the difference in level is $3\frac{3}{4}$ inches and represents about $\frac{1}{8}$ pound per square inch difference of pressure. This difference will fluctuate; the low water-line may be first in one boiler and then in the other, alternating at regular intervals, according

to the firing, or, it may be in one boiler all the time. The former condition is due entirely to the firing, while the latter is due to defective connections. The best way to fire boilers giving unequal water levels is to fire both at the same time, and to fire often.

22. Only low-pressure heating boilers should be connected up with one automatic feeder for all. Power boilers should be fed separately. Heating boilers fed by water of condensation on the gravity-return system cannot be separately connected to a single automatic feeder, unless the steam equalizing header between the boilers is very large, in which case one feeder can do the work. If a separate feeder is attached to each heating boiler in a row, those in which the lowest pressures prevail will receive most of the condensation, while the higher pressure boilers are being supplied through the feeder. In this way, by the low water-lines changing from boiler to boiler, more water will get into the system than is actually required and some of the boilers will become cooled. The only preventive of unequal water-lines is a very large steam header and large steam-equalizing connections, combined with easy-working swing check-valves. The check-valves on the returns really serve only to prevent a too rapid displacement of the water from the boiler and to help to steady the water-lines.

CONNECTIONS TO APPARATUS OF LARGE HEATING PLANTS

FEED-APPARATUS PIPE CONNECTIONS

23. Introduction.—Although the general principles of piping are similar, the accessory apparatus commonly employed in large heating plants differs widely from that used with residential heating systems wherein the water of condensation, for example, is returned to the boiler by gravity. In the large plants, mechanical means are provided for feeding the boilers and returning the water of condensation by injectors, pumps, traps, etc. The manner in which

the different apparatus found in such plants is connected up naturally varies with the design, purpose, and location of the apparatus, and hence specific directions for connecting up that will apply to all cases cannot be given. A

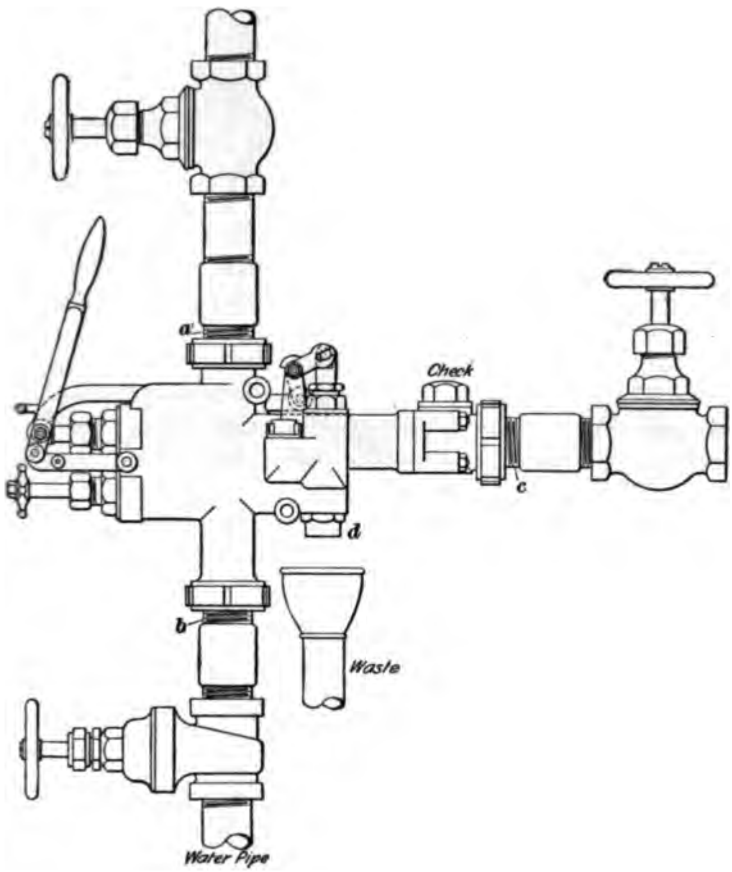


FIG. 7

careful study of the connections to the different kinds of apparatus shown will, however, prove of great value in suggesting means by which extraordinary conditions imposed by local or other considerations may be successfully met. For cutting apparatus out of service, as when repairs are

necessary, without interfering with the continuous operation of the plant, by-passes should be arranged in the piping of auxiliary apparatus, some of which may be advantageously installed in duplicate.

24. Injector Connections.—The injector, of which one type is illustrated in Fig. 7, is sometimes used as an auxiliary to a pump in feeding the water to boilers of the so-called power type. In connecting up the injector, which is placed as near the boiler as possible, commonly at the side, the piping should be as short and straight as possible, avoiding short turns. The steam-supply pipe should not be taken from a steam main but should be attached directly to the boiler, in a place where dry steam is insured, and connected to the injector at *a*, the water-pipe connection being made at *b*, the boiler feed-pipe connection at *c*, an overflow pipe being placed beneath the overflow opening at *d*. The steam pipe is provided with a valve near the injector, and a union for connection, the water pipe also having a valve and union. The boiler feedpipe has a stop- and check-valve, with a union between, so that the injector can be removed with ease without shutting down the boiler. Another or second source of feedwater supply to the boiler should be provided for emergencies, as in case of repairs to the injector.

25. Feed-Pump Connections.—One of the most favored methods of returning water of condensation from heating apparatus, where there is a considerable difference of pressure between the steam in the boiler and that in the heating system, is by using a pump and receiver, one type of which apparatus is illustrated in Fig. 8. This apparatus may be arranged to maintain a uniform supply of water by connecting a cold-water feedpipe *a* to the receiver, as shown. The return pipe *b* from the heating system is connected to the receiver, as shown, a gate valve and a check-valve being placed in the piping to prevent steam or water from passing up the return should there be a pressure in the receiver greater than that in the return. The connection to the

iver has a flange union, as shown, so that repairs may eadily made. As the return water enters the receiver the top through a dry return, the receiver is the lowest

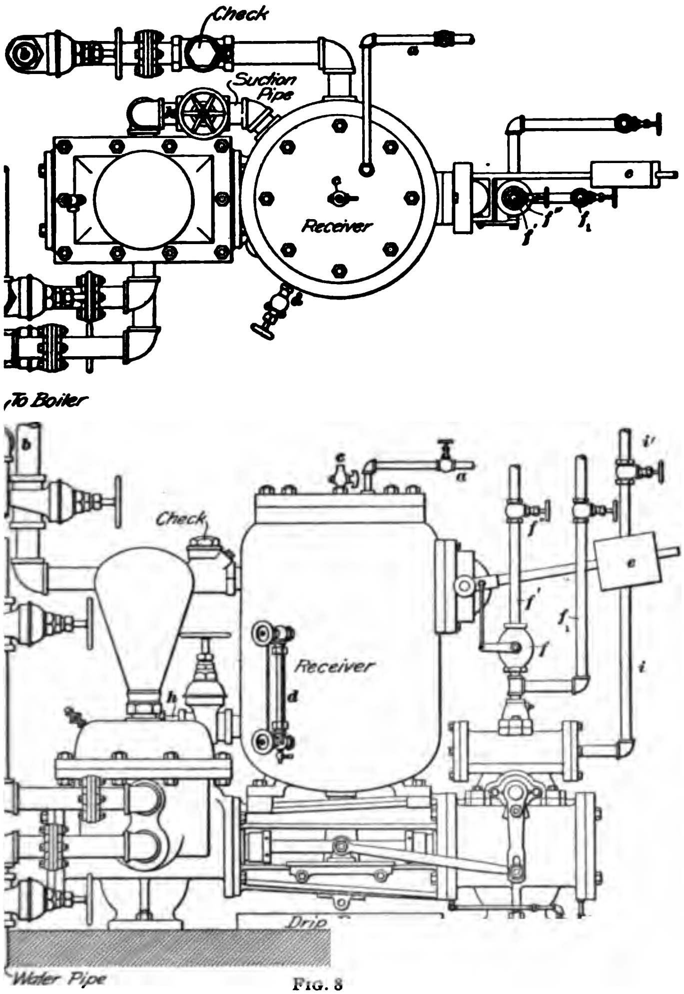


FIG. 8

t of the heating system, which is therefore in balance re the receiver. With a sealed return, where the con- ion rises to the return opening near the top of the

receiver, an accumulation of air would be liable to prevent the water of condensation from flowing freely into the receiver, and hence a small air cock *c* is placed in the top of the receiver, the cock being kept open slightly to allow the steam pressure to drive the air out of the pipes. A gauge glass *d* is employed to show the height of the water in the receiver, while a removable cover gives access to the working parts thereof. In operation, as the water accumulates, the float within the receiver rises, being balanced by the counterpoise weight *e* on the outside lever, to which is attached a toggle that connects to a lever on the valve *f* in the pipe *f'* supplying steam to the pump; when the float has risen to a certain position, the toggle opens the valve on the steam pipe and thereby causes the pump to operate, and when the water falls to a certain point, the toggle closes the valve, and the pump stops. The water of condensation is automatically discharged by the pump to the boiler through the feedpipe *g*, which is connected to the discharge port of the pump, a flange union being used near the pump, and a gate valve being placed in a convenient position in the pipe beyond the union. The water in the receiver reaches the suction chamber of the pump through the suction pipe *h*, which is provided with a valve between the pump and the receiver. In many cases this valve is not provided, but if an additional suction connection, as *h'*, is made to the pump, a valve should be placed in the receiver suction pipe. If this valve were omitted, water from the other suction connection would force the check-valve on the return pipe to close, and hold it so as long as the pressure of the water from the other pipe *h'* is greater than that due to the water and steam in the return pipe *b*. Assuming that the pressures were equal, there might still be trouble on account of a better draft on one suction than on the other. When the amount of water of condensation is not sufficient to furnish the proper supply of water to the boiler, a valve in the small pipe *a* connected to the top of the receiver may be adjusted so that the amount required can be supplied continuously; or, the whole supply may be taken from the main water-suction pipe, which has a valve

l is provided with a flange union, so that it may be readily connected.

26. Fig. 8 serves to illustrate the connections to pumps general, and having described the method of connection r the feedpipes, the other connections, all of which should ave fittings to suit the requirements of position and coneenience, will be considered, the object being to show methods of so connecting up that expansion and contraction will not cause undue stresses on the connections when the steam is turned on and off.

Referring to Fig. 8, the steam-supply pipe f to the pump is ordinarily supplied with an automatic valve f, as shown, but the steam pipe should also have a stop-valve f'' above it, so that the automatic valve can be taken out in case repairs are necessary. For convenience, the valve f'' is placed about the height of a man's upwardly stretched hand, a right-and-left coupling being placed below the valve so that the pump may be readily disconnected. As the receiver float may at times get out of order, which would ordinarily put the pump out of commission, it is advisable to run another steam connection f_1 in the manner shown, so that steam may be admitted to the pump cylinder to operate the pump while repairs are being made to the receiver. The pump may also be made to serve a double purpose, that is, either as a house pump or a direct feed-pump, by providing properly arranged connections. The exhaust outlet is generally at the side of the cylinder, the exhaust pipe i conveying the waste steam to some point where it may be again used, or to the roof to be discharged into the atmosphere. The exhaust pipe is connected up with nipples and elbows, so as to pass up alongside of the steam pipe, as shown, a gate valve i' being placed in the pipe at the same height as the valve on the steam pipe. Gate valves are used where shown because the friction is less in gate valves than in globe valves.

27. Direct-acting steam pumps not only use a very large weight of steam, in relation to the work done, but also

abstract but a small amount of the heat contained in the steam, so that a very large amount of heat is going to waste if the exhaust is discharged directly into the atmosphere. The efficiency of the plant in which the pump is installed can be materially increased by saving some of this waste heat, which is done by using the exhaust steam for heating buildings, drying, warming water, etc.

28. For draining the cylinders of condensation, many manufacturers of pumps and engines provide small T-handled cocks that are troublesome to open when hot, and hence the cocks should be replaced with valves placed in pipes for draining the cylinders, to which the drips are connected at the bottom, as shown, small pipes, with elbows, being carried to the end of the foundation, the valve on each pipe being accessible to the hand. The small drip pipes are connected to a larger pipe, which in turn is connected to some drip receptacle. By means of the valves, the amount of opening required to keep the cylinders free from condensed steam may be regulated. Cylinder drip pipes are sometimes connected to traps, which are, however, only required in cases where condensed steam must be removed continuously without loss of live steam, as occurs in the case of the steam jacket of jacketed steam-engine cylinders, to which steam is admitted at boiler pressure. If in such cases the drip pipes from the engine cylinder itself are also connected to the trap, a check-valve opening toward the trap should be placed in the engine-cylinder drip connection to prevent steam from the jacket reaching the cylinder.

29. Pump-Governor Connections.—The pump governor, an apparatus by which the operation of the boiler feed-pump is automatically controlled so as to maintain in the heating system a fixed water-line, which may or may not correspond with the water-line of the boiler, may be located in any convenient position.

Satisfactory piping connections between the boiler feed-pump *a*, pump governor *b*, and receiving tank *c* are illustrated in Fig. 9. On top of the governor chamber there is

at-operated steam valve *d* that controls the steam sup- to the pump. A lubricator *e* serves to lubricate the ve *d* as well as the pump. The steam-supply pipe for pump is fitted with a by-pass pipe *f* having a valve *f'*, ich, when opened, permits steam to pass directly to the mp when the governor is cut out of service. The gov- nor chamber is connected to the receiver *c* by an equalizing ipe *g* at the top and a pipe connection *g'* to the pump suction ipe at the bottom; this insures that the water in the receiver nd the governor will be at the same level. When pumping

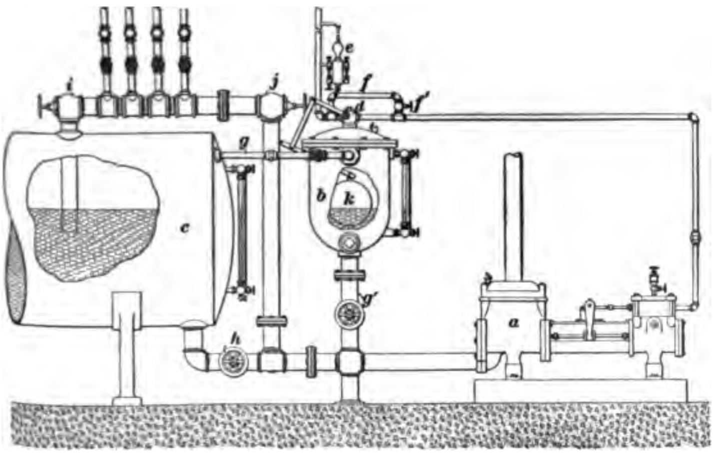


FIG. 9

from the receiver, the valves *h* and *i* are open and the valve *j* in the receiver by-pass pipe is closed. Should any combination of circumstances render it necessary to cut the receiver and governor out of service, the valves *h* and *i* and the valves in *g* and *g'* are closed; the valve *j* is opened so that the water in the returns will flow directly to the pump, both the governor and receiver being out of service. In this case, the valve *f'* in the steam by-pass *f* must of course be open and valve *d* closed. If only the receiver is to be cut out, and the pump governor is to remain in operation while pumping directly from the returns, the valves *h* and *i* and the valve in *g* are

closed; the valve *j* is opened, and, the valve in *g'* being open, the water from the returns will flow into the governor chamber, raise the float *k*, and open the steam controlling valve *d*, which starts the pump. In this case, the by-pass valve *f'* is closed. The pump now lowers the water level in the governor until the dropping of the float *k* shuts the steam valve *d*, which in turn stops the pump until sufficient water has accumulated in the return mains and governor to start the pump again. A small air cock is fitted to the top of the governor chamber; this should be opened when pumping

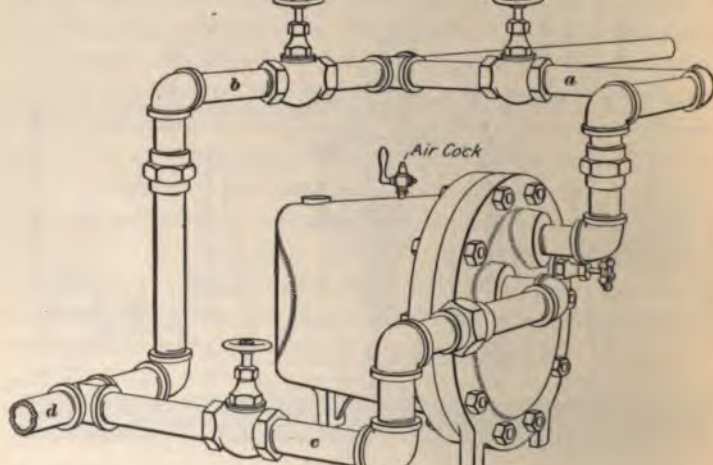


FIG. 10

directly from the returns, in order to insure that the water of condensation will enter the governor. The pump governor can be cut out of service by simply closing the valves in *g* and *g'*; the water can then be taken directly from the returns or from the receiver, depending on the manipulation of the valves *h*, *i*, and *j*. The valve *f'* must be open when the governor is cut out.

30. Steam-Trap Connections.—A good method of connecting up a steam trap is illustrated in Fig. 10. The drip pipe *a* is connected to the inlet of the trap with a union,

:d as near the trap as may be convenient, for easily dis-ecting the trap. A by-pass is formed by the pipe *b* con-:d to the discharge pipe *d*. The trap discharge or waste *c* is connected to the lower opening in the trap, and is ided with a valve, unions being used so that the trap be removed for repairs. In order to allow the steam to by the trap if required, the valves in the pipes *a* and *c*

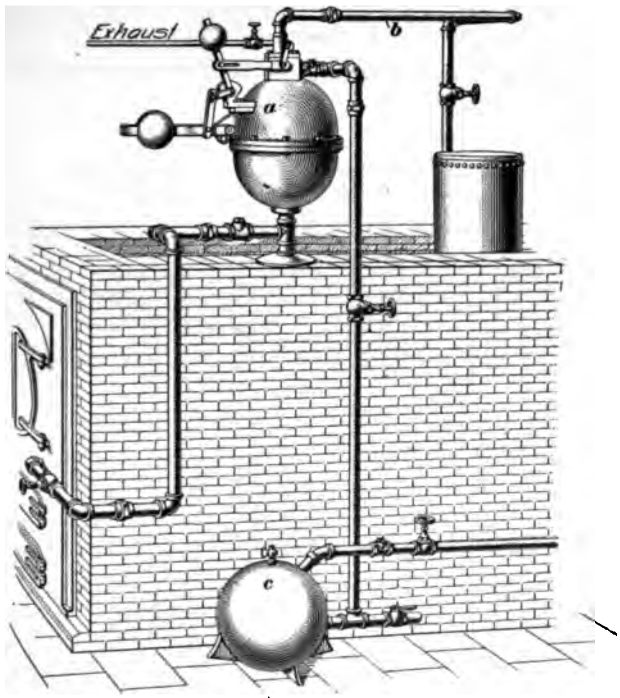


FIG. 11

:losed and that in the pipe *b* is opened. To allow the to discharge the water freely, the waste pipe *d* should t a lower level, unless the pressure within the trap is ient to lift the water discharged by it to a level higher that of the trap; but the pressure on the discharge pipe be less than that in the trap, since otherwise it will not ite.

31. Return steam traps may be connected up as illustrated in Fig. 11. The trap *a* is placed above the boiler, toward which the condensed water flows by gravity, and is provided with pipe connections to the steam and water spaces of the boiler, as shown. Each of these pipes is provided with a globe valve, the water-supply pipe being provided with a globe and check-valve. The steam pipe *b* connects to an automatically actuated double-ported valve, through one of the ports of which steam flows intermittently to fill the receiver of the trap and to equalize the pressure therein. The inlet pipe is provided with a check-valve near the receiver, to prevent the steam from the boiler backing into the low-pressure inlet pipe, and also to seal this port while the water is passing from the receiver of the trap into the boiler. The inlet pipe is connected to a separate receiver *c* to which are connected the return pipes, each of which should be provided with a check-valve in addition to a shut-off valve.

32. Connections to Feedwater Heaters.—In plants where the boilers are used to supply steam for power purposes, and where the exhaust steam from the engines and other apparatus is used for heating, it is advisable—customary, in fact—to use a feedwater heater for the purpose of raising the temperature of the feedwater to as near the boiling point as possible and thereby save fuel, the latent heat in the exhaust steam being utilized for this purpose.

Connections to a feedwater heater of the spiral return-coil pattern are shown in Fig. 12. The exhaust-steam pipe *a* from the engine is connected to the bottom or top of the heater *b*, as convenience may demand. In the illustration, the pipe is shown connected at the bottom, so that the exhaust steam in passing through the heater to the escape pipe *c* at the top will impinge on the surfaces of the copper coil through which the feedwater is forced by a pump to the boiler. The feedwater takes up heat from the steam in its travel to the top of the coil, and as it returns to the other outlet, it is warmed to near the boiling point. Since only a small part of the available heat in the

exhaust steam delivered to the heater by the engine is used in heating the feedwater, a large portion of the remainder may be utilized in warming the building by connecting the discharge or outlet of the feedwater heater with the heating system. An escape, or exhaust, pipe *d* for discharging the

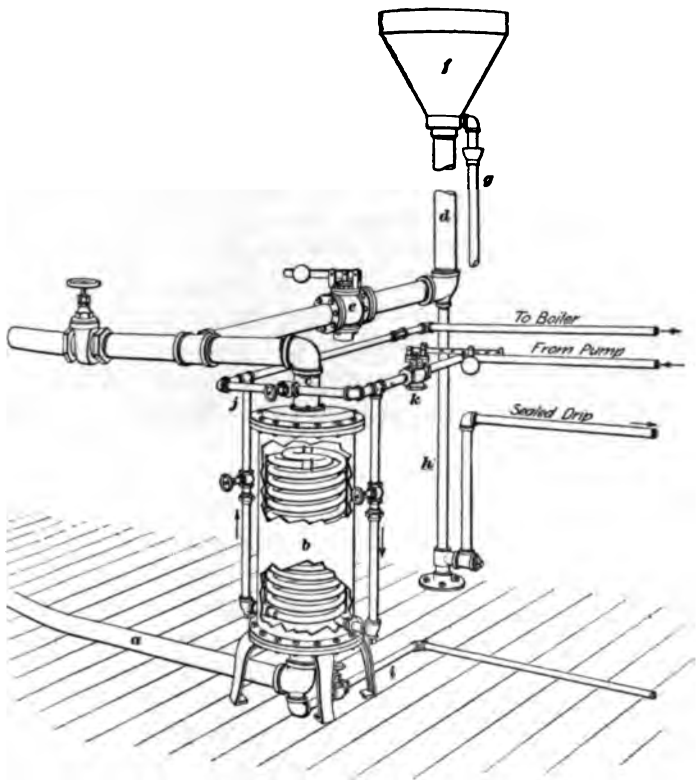


FIG. 12

steam directly into the atmosphere is also provided, as shown, for use in summer and when there is more exhaust steam than is required to do the heating. In order to cause the steam to flow through the heating system and maintain a uniform pressure therein, and at the same time to allow the surplus steam to go to waste in the atmosphere, a back-pressure

valve *e* is placed in the escape pipe, as shown. The escape pipe terminates above the roof in an enlarged cone *f*, called an *exhaust head*, in which deflecting plates are placed to prevent spray, due to condensation of the steam, from issuing from the pipe and scattering over the roof and adjoining property. Spiral riveted pipe is frequently used between the back-pressure valve and the exhaust head, but standard steam pipe is preferable. The water of condensation from the exhaust head flows through a drip pipe *g* carried to some leader or tank, while a drip pipe *h* is carried from the foot of the vertical portion of the exhaust pipe to a blow-off tank, the pipe being arranged with a water seal or trap made of pipe and fittings, as shown. The drip pipe may be made sufficiently large to serve as a support for the vertical exhaust pipe, as indicated. At the bottom outlet of the **T** a plugged nipple is used to close the outlet, the plugging being accomplished by welding an iron plug in the end of the pipe from which the nipple is to be cut. After being forged, the plugged end of the pipe is threaded, the nipple cut off and threaded on the opposite end, the plugged end being screwed into the run of the **T** and the other end into the flange that forms the standard, or foot-piece, resting on the floor. To obviate plugging the nipple, a special flange might be made to serve the double purpose of cap and support. The water of condensation from the heater passes through a drip pipe *i* to some point of discharge below the bottom of the exhaust pipe *a* in order that there will be no accumulation of water to be forced up the escape pipe, and possibly result in damage to the engine or heater. When several pounds back pressure is carried on the engine, so as to use the exhaust steam for heating, the drip pipe *i* in the exhaust line beneath the feedwater heater should be connected to a steam trap below the exhaust pipe. The feedwater connections to the heater may be made in any convenient way to suit the requirements, but they should be so arranged that the valves thereon are accessible. Gate valves only should be used, unions being provided to permit disconnecting; the pipes being so arranged that when disconnecting is necessary

ectly to the boiler through a
valve, as shown, just above the
g may be arranged to take any
n such a manner as to present a
point in the feedpipe, at or near
should be a safety valve, as *k*,
or heater by an overpressure
be caused by the operation of
in the feedpiping should happen
the heater at a distance from

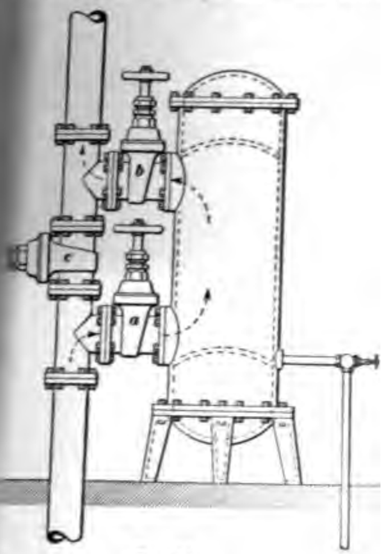
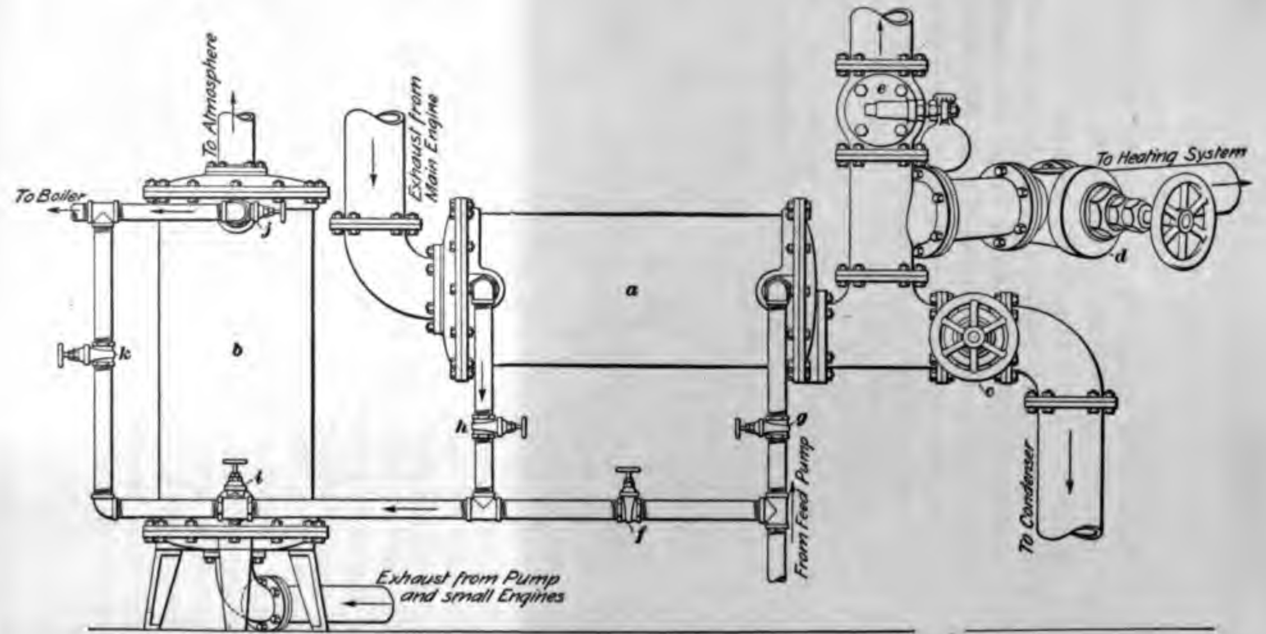


FIG. 13

this method of piping is used, the
gh heater, in order to distinguish
-called *induction type*, wherein the
to travel from the exhaust main
owing to the condensation of the
the cold water passing through
Provision for cleaning or repairs is
ass connection, so that by closing
pening the valve *c* the heater may



To Atmosphere
Exhaust from Main Engine
To Heating System
To Boiler
a
b
c
d
e
f
g
h
i
j
k
From Feed Pump
To Condenser
Exhaust from Pump and small Engines

34. When exhaust steam is utilized for heating in plants where there is considerable auxiliary apparatus, such as steam pumps, small engines, or other steam-using devices, a secondary or auxiliary heater into which they may exhaust is frequently provided, a common arrangement of piping them being shown in Fig. 14. The main exhaust-inlet connection to the primary heater *a*, which is usually placed in a horizontal position directly in the main exhaust line, is generally concentric with the head at one end of the heater, the outlet connection being placed at the bottom of the heater so as to relieve it of water of condensation. The feedwater passes from the primary to and through the secondary heater *b*. The exhaust steam passes through the heater to the condenser (an apparatus for condensing the steam so as to secure the economy or increase of power due to the vacuum thus produced) when the gate valve *c* is open, the valve *d* being closed, as in summer, when the heating system is not in use; or, to the heating system when the valve *c* is closed and *d* is open, and the back-pressure valve *e* closed; or directly to the atmosphere when the valves *c* and *d* are closed and *e* open. The exhaust steam from the auxiliary apparatus enters the secondary heater at the bottom, as shown, and passes out at the top into the atmosphere, a drip connection being provided, as in Fig. 12, through which the water of condensation is discharged to the sewer.

By means of by-passes in the feed-piping, either or both of the feedwater heaters may be used or cut out of service, the feedwater being pumped directly to the boilers in case of necessity. The feedwater passes through the coil of the primary heater when the valve *f* is closed and the valves *g* and *h* are open. When the latter valves are closed and the former open, the feedwater passes through the auxiliary heater, provided that the valves *i* and *j* are open and *k* is closed. The secondary heater may be cut out by closing valves *i* and *j* and opening *k*. If *g* and *h* are also closed, *f* being open, the feedwater passes directly to the boilers without being heated. It is considered good practice to make the two heaters of equal capacity. Live steam, taken directly

from the boilers through a reducing valve, is often used t compensate for any deficiency in the available amount exhaust steam.

35. Oil-Separator Connections.—The exhaust stea used for heating or other purposes should be cleared of th oil carried in it from the cylinders of engines, pumps, et The apparatus com monly used for th purpose has either d flecting plates, tube screens, or other in tercepting devices c which the globules oil and water in th steam impinge befo falling into a collec ing chamber, fro which the conten may be discharg e to the sewer or in

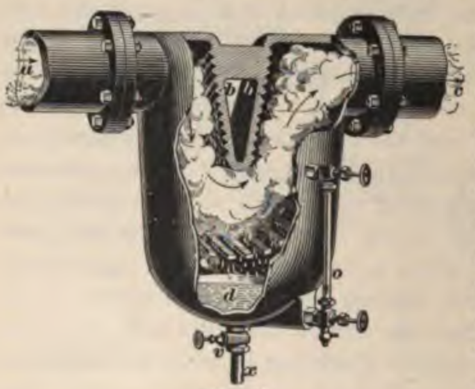


FIG. 15

some other receptacle. Oil-separating devices are various called *oil separators*, *eliminators*, or *oil extractors;* they a either placed in the exhaust-pipe line from the engine, or o the main line of the heating system.

36. Fig. 15 shows a separator of simple constructio The steam enters through the pipe *a*, the general directio of its travel being changed by the corrugated baffle-plat partitions *b*, *b*, to which the oil and particles of moisture in the steam adhere, while the purified steam passes to and out through the pipe *c*. The moisture and oil that collect on the baffle plates run to the bottom of the separator at *d* through grooves provided for that purpose, the contents of the separator being indicated by the gauge glass *o*.

37. When oil separators are applied to an exhaust pipe, they are usually placed below and close to the engine, the oil and grease collected by the separator being discharged into the sewer. Fig. 16 shows the application of an oil

separator to a heating main in a case where the exhaust steam from an engine is used for heating. The steam delivered to the heating apparatus is thereby freed from the heavy oil that would otherwise clog the pipes. The water of condensation, if desirable, can be used again in the boiler. The drip-pipe connection *a* taken from the bottom of the separator

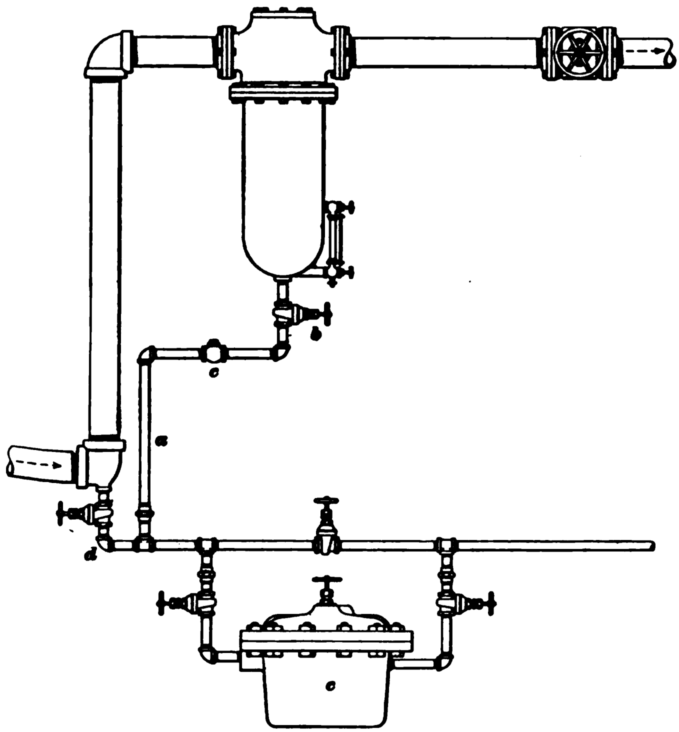


FIG. 16

should be provided with a gate valve *b* to shut it off when it is desired to clean the pipe, and a check-valve *c* should be placed in this drip pipe to prevent the exhaust-pipe water or other drain water backing up the pipe *a*, which may be connected to a drip pipe *d* from the exhaust, or to some other pipe under the same pressure. Should the separator drip be connected to a pipe under a lower pressure, the exhaust

steam in the separator would flow through into this latter pipe, in which case the gate valve would have to be partly closed to prevent waste. The gauge glass, provided to show an accumulation of the oil and water in the chamber, serves to show the attendant when it is necessary to empty the chamber; in case a trap is provided, an undue accumulation of water and oil shown by the gauge glass indicates failure of the trap to work properly. As shown, the exhaust-pipe drip and separator drip may be connected to the same trap *e*, thus saving the expense of the additional trap needed if they were run separately. Steam traps are always required when drip pipes are to be connected to a receptacle or pipe having a lower pressure than exists in the pipe to be drained.

38. Combination Separator and Tank Connections. Fig. 17 shows a combination of apparatus known as the Utility exhaust muffler, oil separator, return tank, pump governor, and feedwater heater. This apparatus is designed for use in office buildings, hotels, factories, and all buildings where exhaust steam is employed for heating and manufacturing processes, and where the returns are fed to the boilers. The make-up water, or water required to compensate for loss by drips, etc., is heated by exhaust steam in a relatively small feedwater heater *a* at the side of the muffler tank *b*. In such installations, it is necessary first to separate the oil and water from the exhaust, to provide storage capacity for the drain water from the returns, and means for effectively heating the cold water introduced to make up losses. The exhaust pipe *c* from the engines drops from a 90° elbow to a 45° elbow, and then to the tank, so that the grease and water passing along with the steam will be deflected to a perforated plate beneath and thence through the links of a series of suspended chains that are free to vibrate while the oil and water in the steam are being separated. Expanding into the receiving chamber of the muffler tank, the exhaust steam passes with a greatly diminished velocity through the upper portion of the tank, which is filled with the iron chains suspended in semicircular frames,

t closely together. The frames are secured in the shell by liagonal brace against the one nearest the inlet pipe. By moving a plate that is bolted on to the rear head and a ace that bolts to the floor of the receiving chamber, the ımes and chains can all be removed for cleaning. The oil d water arrested by the chains is free to drip to the bottom

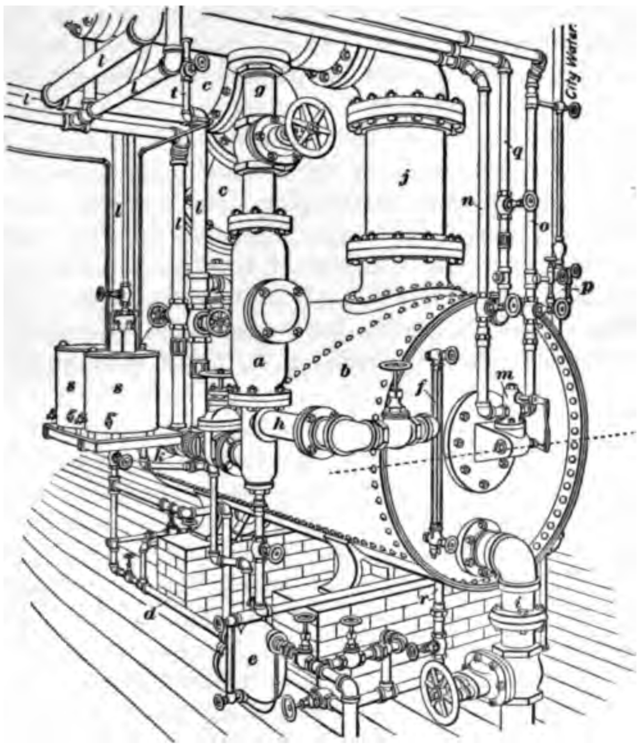


FIG. 17

the tank, whence it flows to a trap that is behind the rear ick pier, and which cannot be seen in this illustration. 'om this trap the drips are conveyed by the pipe *d* to the wer. A glass gauge *f* is provided in the front head of the ık to show the height of the water in *b*. By-pass valves ıy be provided so that the water from the returns may be

discharged through a trap to the sewer in case it may temporarily be desirable not to return the water to the boilers.

The pipe shown connected to the trap *e*, and which is by-passed into the pipe *r*, takes the drips from the separators on the high-pressure steam lines. The high-pressure drips are discharged directly into a front compartment of the tank by means of the trap *e* shown in the foreground. The low-pressure returns enter the bottom chamber of the feedwater heater *a*, and, passing upwards through the annular portion of a central pipe column within the latter, are discharged against the under surface of an umbrella-shaped spreader. The cold make-up water, which also enters at the bottom of the feedwater heater, passes up the small central pipe, discharging over the umbrella in a spray or thin sheet, and mingles intimately with the exhaust steam that enters the chamber of the feedwater heater at the top through a pipe *g* taken from the tank outlet piping *j* after the exhaust steam has passed the chain separator.

The fresh feedwater, heated to within a few degrees of the temperature of the exhaust steam, is discharged from the central compartment of the feedwater heater through the pipe *h* to a chamber in the front of the muffler tank, from which it is drawn off to the boilers, as required, through the suction pipe *i*. The exhaust steam escapes to the heating apparatus at the front end of the tank through the pipe *j*. All connections are made with flanged fittings, as the available space would not permit the use of screwed fittings on pipe of such large size. The joints between the flanges are made up with some kind of composition rubber gaskets about $\frac{1}{8}$ inch thick, and are secured by means of bolts. The supply of cold water can be regulated so as automatically to make up any deficiency in the amount secured by the condensation of the exhaust steam in the heater and that supplied by the condensation returned from the heating apparatus. The return pipes, which are run above the muffler tank and are therefore dry returns, are connected into the feedwater heater at a point *k* below the level of the pipe *h* through which the fresh feedwater flows to the front compartment of the

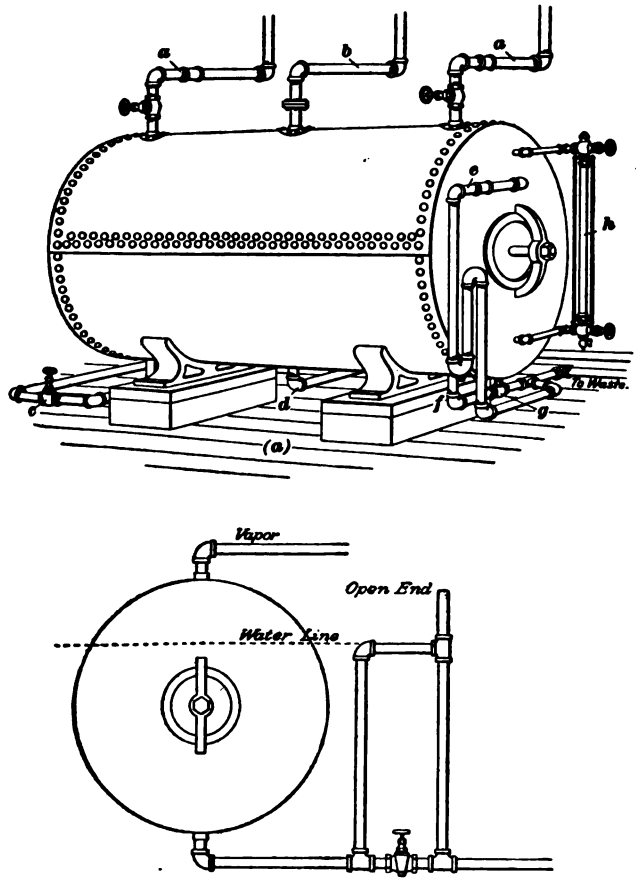
muffler tank, thereby forming a water seal for them. The drip pipes *l*, *l* from the heating main drop into the main return header *k* and are thereby also sealed, and each pipe is fitted with a hand valve, as shown, at a convenient height, below which the final right-and-left coupling connection is made. An automatic pump-governing, or regulating, valve *m* is fitted to an extension on the front head of the tank and connected to a float within the tank; by means of levers, the valve is opened when the water in the tank is high and closed when the water is low. The steam-supply pipe to the pump is connected to this valve, so that the pump will operate automatically. The pipe *n* at the left of the valve connects to the steam chest of the pump, while the other pipe *o* connects to the main steam supply. On the steam-supply pipe to the regulating valve is attached a sight-feed lubricator *p*, so that the steam, in passing through the valve and to the pump, receives the lubricant for the cylinder of the pump and at the same time lubricates the valve. Near the top of the head of the tank is an equalizing pipe *q* to secure in the tank the same pressure as in the heating main. At the bottom of the front head is the suction pipe *i* to the feed-pump, which is some distance from the tank, and also the blow-off pipe *r*, and in the rear head there is an additional blow-off pipe and an overflow pipe. These pipes are fitted with valves, and are connected to one pipe *d*, which runs to a hotwell or to a sewer. Two small condensers *s*, *s*, placed beside the tank at the left, are used for taking samples of water to show the difference between the water of condensation from steam taken from the mains before, and that secured after, the steam has passed through the muffler tank extractor, and also to show to the engineer whether the water fed to the boilers is free from oil. The piping for these is small, but the connection *t* at the main is enlarged to allow a free inlet to the pipes, which, being taken from the bottom of the main will permit any oil or grease to drain to the condenser. The condensers contain coils through which steam passes from the exhaust pipe; in the one case before, and in the other after, the steam has passed the bank of chains.

Cold water surrounds these coils and the condensed steam when drawn off through the small faucets is oily before and should be clear and bright after passing the tank separator. It can readily be seen that by this process of purifying the exhaust steam a considerable saving can be effected, as the drips from exhaust lines, risers, exhaust head, feedwater heater, and all other waters of condensation can be saved. In fact, there need be no loss of water except that of dirty engine and pump cylinder drips. The condensers and the drip tray on which they are set may be piped in a variety of ways according to the conditions surrounding the installation, the main point being to take the supply connections from the proper lines and to connect up all drips to the sewer.

TANK PIPING CONNECTIONS

39. Blow-Off Tank Connections.—Blow-off tanks and drip tanks are required in cities where the waste water from steam apparatus is discharged to the sewers. These tanks are fitted up in such a manner that the water from them can be cooled to a moderate temperature in order to prevent the hot water or steam otherwise discharged from destroying the joints in plumbing pipes connected to the sewer, and also to prevent the presence of vapor in the sewers. The tank should have a vapor pipe or vent of ample size to the atmosphere, in no case less than 2 inches in diameter, and where there is a large volume of steam it should be 4 inches, or larger. This pipe should have no valve, except when conditions are such as to make it necessary to force the water out of the tank by pressure. The vapor pipe must be taken from the top of the tank and carried to and above the roof, where it should be provided with an exhaust head to prevent the condensing vapor from falling in a spray on the roof. The drip pipes from steam-using machinery should be brought in at the top of the tank so that such machinery will be properly drained; or, if this is not practicable, they may be connected to the bottom, but the tank itself must be below the level of the apparatus from which the drip pipe is taken.

Fig. 18 shows two drip pipes *a*, *a* at the top of the tank, the vapor pipe *b* being located at the center between the two drip pipes. All these pipes are on the same level just above the tank, from which they are carried back to allow



(b)

FIG. 18

spring for making the final connections by right-and-left couplings or flange unions. Stop-valves are placed in the drip connections near the tank. The blow-off pipe *c* from the boiler is shown coming in at the bottom; the pipe is led

either around the end of the tank to follow the wall or to suit other conditions; a valve, accessible to the hand, is placed in the connection. A drip pipe *d* is shown connected to the bottom of the tank, and is also provided with a stop-valve or check-valve at some convenient point. At the end are shown the overflow pipe *e* and blow-off pipe *f*. As shown in Fig. 18 (*a*), a cock *g* is placed in the blow-off connection to the bottom of the tank for use when the tank is to be emptied. Beyond the cock is a **T** to which the

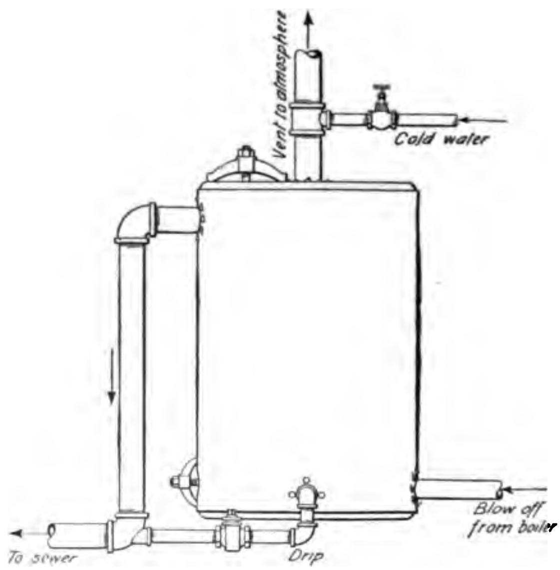


FIG. 19

overflow connection is made, the pipe then being carried to the sewer outlet on the sewer side of the house trap, thereby preventing the vapor from flowing up the drain pipes. The overflow pipe can be taken from the tank at a point above the manhole, as in Fig. 18 (*a*), or it can be connected at the bottom, as in Fig. 18 (*b*). In the former case, the pipe must have a trap or water seal, made as shown, to prevent steam or vapor passing to the sewer; where the pipe is taken from the bottom, there must be a siphon-like trap to

preserve the water at a given line in the tank. These pipe traps may be made of ordinary pipe and fittings, and should be placed outside the tank, where they are accessible for making repairs. The tank should be fitted with a water-gauge glass, as *h*, Fig. 18 (*a*), to show the height of the water in the tank; this can be fitted into either head, but is generally placed at the manhole end, as there is always room at this end for it, which room must be given for access to the manhole.

40. Fig. 19 illustrates the piping connections to a vertical blow-off tank, into which the water blown off from the boilers is discharged under pressure near the bottom of the tank, and when the latter is nearly full the water flows by gravity to the sewer through the pipe shown at the left of the tank, from which a drip connection to the discharge pipe is taken near the bottom, as shown, for draining the tank. A vent-pipe opening into the atmosphere is provided at the top of the tank, where provision is made for the injection of cold water whenever necessary to reduce the temperature of the water flowing from the tank to the sewer. Handholes at the top and bottom provide access to the tank for cleaning.

41. Hot-Water-Tank Connections.—Hot-water tanks having steam coils in them to heat the water are frequently hung from the ceiling by heavy flat wrought-iron straps, securely fastened to support the weight of water and tank, so that any jarring of the floor above will not cause the tank to fall. A better way of supporting such tanks is to construct a stand of pipe or angle iron to support them from the floor, as ordinary building beams are seldom sufficiently strong to safely bear the extra weight of the tanks. The steam connection to the coil should, where possible, be neatly run near the wall to allow as much headroom as may be had, as in Fig. 20, which shows the steam connection *a* to the coil made at the top of the tank. In this pipe, a valve *b* should be so placed that the steam may be shut off, and between this valve and the tank is placed a diaphragm steam-regulating

valve *c* operated by water or air pressure sufficiently great to actuate the diaphragm so as to close the valve when the water has attained a certain temperature, say, 180°. The actuation of the diaphragm steam-regulating valve *c* is brought about by the expansion and contraction of a liquid within a tube that is attached to the head of the tank, and, projecting inwardly, is surrounded by the water of the tank. When the water in the tank has reached the desired tempera-

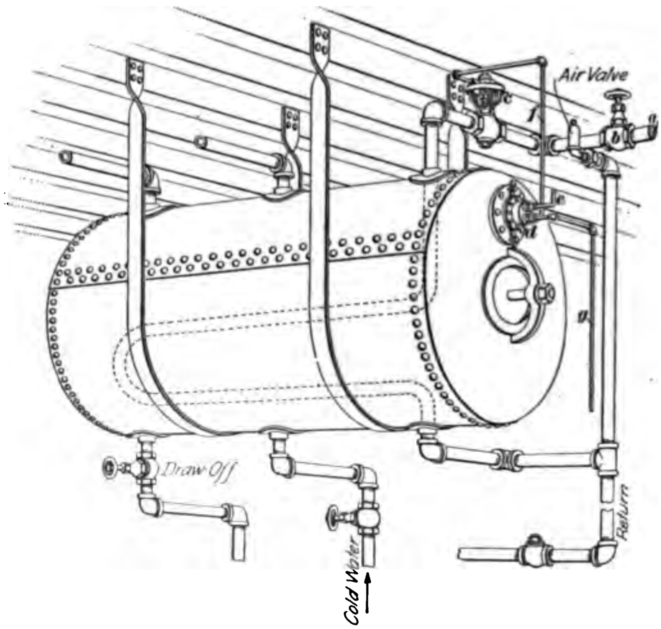


FIG. 20

ture, the expansion of the liquid within the tube causes a diaphragm valve-actuating mechanism *d* to open a valve by which communication with the cold-water supply system is established through the pipe *e*, and water under the street-main pressure is thereby caused to flow through the pipe *f* to the diaphragm chamber of the regulating valve *c*, actuating the diaphragm so as to close the valve and thus shut off the supply of steam to the coil. When the temperature of the water within the tank falls, the pressure on the diaphragm of

the water-supply, valve-actuating mechanism d is reduced by the contraction, due to the cooling, of the liquid within the tube, the water-supply valve being thereby closed and an escape valve being opened, so that the pressure on the diaphragm of the steam-supply regulating valve c is correspondingly reduced. The steam-supply valve is then opened by the action of spring attached thereto, as shown, to admit steam to the coil. When the water supply is cut off by reduction of the temperature of the water in the tank, the water that escapes through the pipe g may be discharged through a waste pipe to the sewer. The return pipe from the steam coil is carried back to the wall, as shown, and to a **T** therein is connected a small pipe, at the top of which an air valve is placed; the return then drops to the main return pipe near the floor, where it should be provided with a check-valve. When the hot-water tank coil is connected to a low-pressure heating system, the return may be connected as shown, but when high-pressure steam is used on the coil, the return must be connected to a steam trap arranged with a by-pass.

STEAM-MAIN CONNECTIONS

42. High- and Low-Pressure Heating Main Connections.—Where high-pressure steam is used for power and other purposes, connections between the high-pressure main and the heating apparatus is commonly made, as indicated in Fig. 21, through a reducing valve a by which the pressure in the heating main b is reduced as nearly to atmospheric pressure as possible. High-pressure steam increases in volume as its pressure is reduced by expansion in passing through the reducing valve, which is so designed as to allow the free passage of the increased volume of steam with the least practicable amount of friction, the steam expanding in the main and circulating with a low velocity. The reducing valve is made with an outlet twice the diameter of the inlet, as indicated. The valve in the body is a double-disk piston with both disks under the same pressure. The spindle, or stem, of the valve is actuated by

a diaphragm placed in a separate chamber beneath the valve body, the diaphragm chamber being connected to the low-pressure main, as shown. A weighted lever holds the valve open until the required pressure in the low-pressure main forces the diaphragm to push the piston into the proper position to give the pressure needed on the low-pressure side. The high-pressure steam main *c* is connected up with a gate or globe valve, adjacent to which a **T** should be placed to allow a by-pass *d* to be run around the reducing valve, which may then be taken out for repairs if necessary. A globe

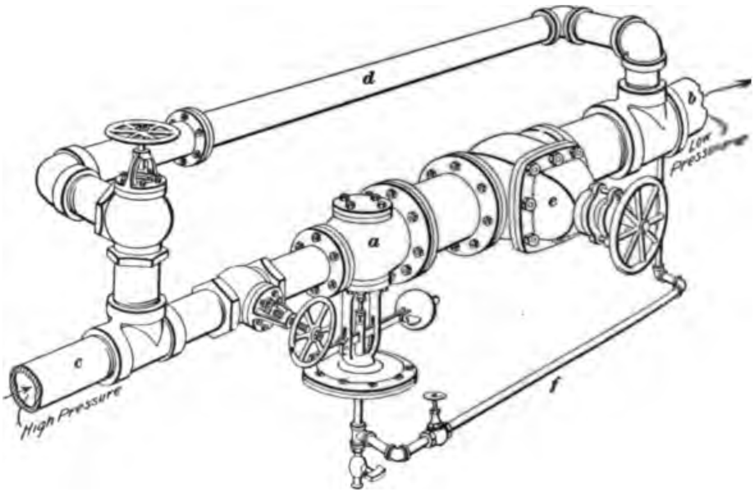


FIG. 21

valve or angle valve, as the available room may permit, should be placed in the by-pass piping, as indicated. If an angle valve is used, there will be a saving in labor and fittings. This valve should be connected so that it will close against the pressure, and the pipe, in order to allow the reducing valve to be removed, should be run so that there will be some spring between the points where it connects to each of the other pipes. At the low-pressure side of the reducing valve is placed a gate valve *e* that may be closed when repairs to the reducing valve are necessary. The high-pressure by-pass piping connects into a **T** on the low-pressure

main, as shown. There should be a valve on the pipe *f* that connects the diaphragm chamber with the low-pressure main, which valve is closed when repairing the reducing valve and using the by-pass connection. A drain cock is provided to drain the diaphragm chamber of water of condensation. The reducing valve is made with flanged ends and is connected to the pipes by similar flanges, the gate valves also having flanged ends, the flanges being bolted together with some form of packing between them. A pressure pipe *f* transmits

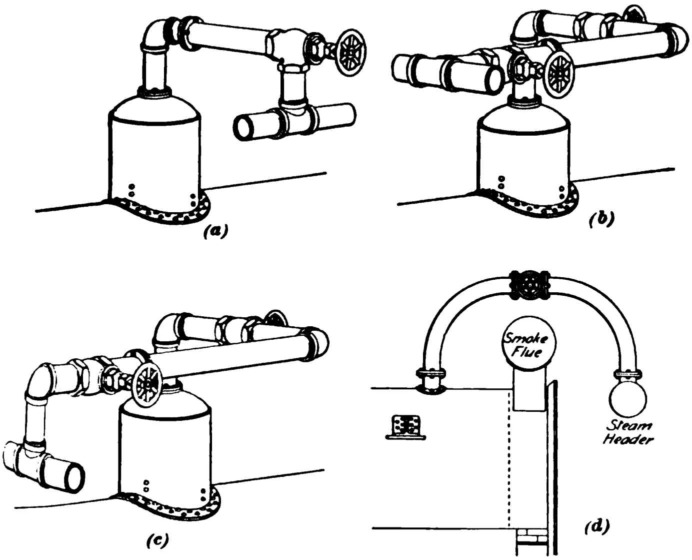


FIG. 22

the pressure in the low-pressure main to the bottom of the diaphragm of the reducing valve.

43. Connections of Main to Boilers.—Careful thought is necessary in designing piping connections to boilers. Connections between a single boiler and the distributing main are comparatively simple to make, but when two or more boilers are to be connected to the same main line of pipe, special and adequate provision must be made for expansion, otherwise the stresses on the connections will cause them to leak. In connecting a single boiler to the

steam main, the method shown in Fig. 22 (*a*) may be followed, provision for lateral expansion being made by placing an angle valve, as shown, to serve for a swivel connection. The connection shown in Fig. 22 (*b*) provides for upward or downward expansion, the connection to the main being made long to allow for some spring in the pipe when the latter is of small diameter, but where large pipe is used, allowance for expansion in all directions must be made so as to minimize the stress on the fittings, as illustrated in Fig. 22 (*c*). In the connections shown in Figs. 22 (*b*) and (*c*), two stop-valves are used; the one near the main has its seat to the pressure on the main, while the other has its seat to the pressure on the boiler. Hence, if the boiler is to be tested, the valve on the boiler can be closed, and the pipe between the valves be without pressure, or, if the manhole is taken from one boiler for inspection, the leakage of one valve can be stopped by the other. A small drip pipe with a valve in it should be placed between these valves, so that the leaking of either can be detected.

Wherever the height of the boiler room will permit them to be used, bent pipes are commonly employed in making boiler connections on first-class work, for instance in the manner shown in Fig. 22 (*d*). These bends are usually made of extra strong pipe, the radius to which they are commonly bent to give them sufficient spring being equal to about seven times the diameter of the pipe. A shorter radius should never be used, as in making shorter bends the pipe is strained too much at the throat, or outer radius, while the compression on the heel of the pipe or inner radius tends to cause the pipe to bulge sidewise, and throw it out of round, weakening the metal. With bent pipes, the best position for the valve, when only one is used, is at the center of the bend, but some engineers regard the practice of using two valves as being somewhat better, one of the valves being placed near the main and the other at the boiler. Where two valves are used, it is necessary to tap into the body of each valve for a drip connection to drain away any water of condensation that may accumulate therein.

AUTOMATIC SPRINKLER SYSTEMS

GENERAL DESCRIPTION

44. Owing to the inflammability of materials contained in many buildings, such as mills and factories, and owing to the immense amount of such materials stored or handled in these buildings, and still further, owing to the intensely high pressure with which everything is accomplished in these modern institutions of industry, it has been found that fires frequently play great havoc in them. When a fire starts in a large building that is stocked with inflammable material, the entire building and its contents are usually completely ruined, if an efficient fire-protecting system is not in force. Fires in such buildings spread rapidly, and instant action is necessary to extinguish them while they are in the incipient stage. To this end, numerous fire-extinguishing appliances have been contrived and are being used. None of them, however, act more efficiently in mills and factories than automatic sprinklers. While such systems are generally installed by the makers of the apparatus, heating engineers are occasionally called on to do this work, and hence should be familiar with modern practice in this respect.

Automatic sprinkler systems are composed essentially of a number of sprinkler heads (which are nozzles) distributed through the entire length and breadth of the rooms to be protected. They are placed equidistant to one another, and when they are operating, throw a heavy spray into the building at the places affected by the fire. The spray is turned on automatically by the flames melting a fusible part of the sprinkler head, which lets a valve fly open and the water flow out. In combination with the sprinklers is a system of iron pipes that supplies the sprinklers with water under pressure from a tank located on the roof of the building, or by water under pressure from the street mains, or a pneumatic supply tank in the basement.

SPRINKLER HEADS

45. There are many kinds of sprinklers on the market, but in a general way they all operate in a similar manner. Figs. 23 and 24 illustrate a common form, known as the Walworth automatic link sprinkler. Fig. 23 shows it closed and ready for action; Fig. 24 shows it open after the fusible link has been melted apart. The valve in this sprinkler is held to its seat by a bell-crank secured at its upper end by fusible links, each made by bending a strip of sheet brass about $\frac{1}{4}$ inch in width to the form of a **U**, each piece being of the same size. These pieces are carefully soldered together to form a link, and are therefore free to break apart when the

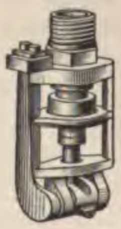


FIG. 23

FIG. 24

solder melts. The solder used in joining the links is an alloy having a very low melting point. When the bell-crank is raised and the link put on top, the valve is pushed tightly up against its seat; a thin copper washer being placed between the valve and the seat to prevent adhesion, so that when the link is melted and the bell-crank relieved, the valve will open freely with the pressure. The bell-crank is thus thrown over and the sprinkler assumes the form shown in Fig. 24, when a stream of water flows directly against the distributing, or "splash plate," which is the valve, and spreads itself in a heavy spray throughout the room. This valve has been extensively introduced in manufactories throughout the United States, and has a record of clear operation at a large number of fires. There are other sprinklers, however, that

have good reputations also, for example: The Grinnell automatic sprinkler, the Esty sprinkler, the Non-Corrosive sprinkler, the Hibbard sprinkler, and others.

46. Figs. 25 and 26 show the Esty sprinkler closed and open, respectively. In this, as in the Grinnell, the Non-Corrosive, the Hibbard, and others, the parts that hold up the valve to its seat are melted asunder, which along with the valves, are thrown to the floor when the solder is melted. In Fig. 25, the sprinkler is of brass, seated with mica, which makes it non-adhesive. The strut that holds up the valve is composed of two pieces of cast brass that are joined together by a low-temperature fusible solder. The soldered joint projects from the center, rendering it accessible to a sudden fire,

FIG. 25

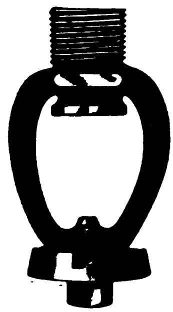


FIG. 26

and as the strut swings on a center pivot, it will stand considerable abuse from violence before the valve can be opened sufficiently to allow leakage. Between the arms of the strut is a small cavity in which is placed a small japanned spring. This spring is held in a state of tension and exerts a constant positive force, more effective than 300 pounds water pressure. This assists in throwing the strut apart the instant the solder reaches the fusing point. The cavity that holds the spring is filled with wax that melts at a temperature of a few degrees below the fusing point of the solder and protects the spring against corrosion. Over the extreme end of the strut is placed a small U-shaped piece of German-silver spring wire, which passes under one arm, up over and around each

side of the web of the other arm, where it is soldered in place. This strengthens the solder joint and prevents the gradual yielding and accidental rupture of the fusible solder. When the fusible solder is softened by the heat of a fire, the strut falls apart and the mica-seated valve, no longer held to its seat, is thrown off. The escaping water impinges on the deflector at the bottom of the sprinkler and spreads a profuse shower in all directions.

47. In all places where corrosive fumes abound, such, for example, as bleacheries, paper mills, tanneries, match works, chemical works, etc., the sprinklers should be protected by a coating of wax to prevent corrosion of their parts. The wax coating commonly used is a specially prepared mixture for sprinklers. It melts, under test, at about 160° F., which is a few degrees below the fusing point of the special soft solder used in closing sprinklers, and therefore does not affect the sensitiveness of the sprinkler.

Under ordinary circumstances, a sprinkler should open and throw a stream when the temperature of the soldered parts reaches 165° F.; but for boiler and engine rooms, dry rooms, and such places, high-test sprinklers are used. The kind of solder employed should be in accordance with the work. There are four grades of solder in common use, one that fuses at 165°, another at 212°, another at 280°, and another at 360°.

48. Special large sprinklers are used in elevator shafts, light wells, and other such places where a large quantity of water would be required in case of fire. The nozzles of these sprinklers should be at least 1⅛ inches in diameter. All sprinklers should be tested before being put on the job. It is customary for the manufacturers to test them to an air pressure of 300 pounds per square inch. The releasing mechanism of all sprinklers should be so constructed as to part the instant the solder fuses and before the valve has left its seat. If the valve is not kept closed until the solder joint is entirely broken, a slight escape of water might cool and reset the fusible solder when the valve is but slightly opened,

and thus defeat the working of the sprinkler. A serious objection to a sprinkler system has always been the accidental opening of the sprinklers either through the fusing joint becoming corroded, or from the jar of machinery, or from the accidental striking of a sprinkler head. With a view to reducing this danger, the Walworth sprinkler is equipped with a safety link. This link is simply larger than the one that holds the valve closed, and is subject to no stress. But, should the inner link become ruptured, the safety link would still hold the lever in position and allow only a very fine spray of water to escape. This outer link fuses at a lower temperature than the inner length, thus insuring prompt action of the sprinkler. Another advantage of the Walworth sprinkler is that new fusible links can be applied periodically at any time, every year if necessary, thus making it as sensitive as when first put up. Still another advantage of this sprinkler is that after a small fire it can be instantly closed and placed in perfect working order by simply lifting the bell-crank and putting on new links, thus preventing serious damage by water and giving an uninterrupted protection to the building.

WATER SUPPLY

49. Automatic sprinkler systems should be provided with two sources of water supply, one of which should constantly be turned on the sprinklers; the other one, preferably from an approved fire-pump, should be used automatically as an auxiliary supply. Check-valves placed on the main supply pipes from these two sources and opening toward the sprinklers will permit water to flow to the sprinklers from whichever source of supply has the greater pressure. This avoids the necessity of manipulating valves, which in case of a fire is undesirable.

50. The following table of the Factory Mutual Insurance Companies gives the proper distance between sprinklers, and is the result of their broad experience in the application of automatic sprinklers. The headings Medium Hazard and

Special Hazard relate to the contents and character of each room. Specially hazardous places are such as planing or sawing departments of wood-working mills, painting and varnishing rooms, etc.

In all cases the distance from walls to nearest sprinklers should not exceed one-half the distance between the sprinklers in the same direction.

SPRINKLERS FOR STANDARD MILL CONSTRUCTION

ONE ROW OF AUTOMATIC SPRINKLERS IN EACH BAY PLACED MIDWAY BETWEEN BEAMS

	With Water Pressure at Highest Sprinkler			
	Exceeding 20 Pounds per Square Inch		Less Than 20 Pounds per Square Inch or Supplied Primarily by Tank	
	Medium Hazard	Special Hazard	Medium Hazard	Special Hazard
In 12-foot bays . .	8 ft. apart	7 ft. apart	7 ft. apart	6 ft. apart
In 11-foot bays . .	9 ft. apart	8 ft. apart	8 ft. apart	7 ft. apart
In 10-foot bays . .	10 ft. apart	9 ft. apart	9 ft. apart	8 ft. apart
In 9-foot bays . .	11 ft. apart	10 ft. apart	10 ft. apart	9 ft. apart
In 8-foot bays . .	12 ft. apart	11 ft. apart	11 ft. apart	10 ft. apart
In 7-foot bays . .	12 ft. apart	11 ft. apart	11 ft. apart	10 ft. apart

SPRINKLERS FOR OPEN-JOISTED CEILINGS

SPRINKLERS SHOULD PREFERABLY BE PLACED DIRECTLY UNDER A JOIST

	With Water Pressure at Highest Sprinkler			
	Exceeding 20 Pounds per Square Inch		Less Than 20 Pounds per Square Inch or Supplied Primarily by Tank	
	Medium Hazard	Special Hazard	Medium Hazard	Special Hazard
At right angle to joists	8 ft. apart	$7\frac{1}{3}$ ft. apart	$7\frac{1}{3}$ ft. apart	$6\frac{1}{3}$ ft. apart
Parallel with joists	10 ft. apart	9 ft. apart	9 ft. apart	8 ft. apart

Fig. 27 shows a system of piping installed in a large aving a combination of street-pressure and tank-pressure supply. A check-valve is located on the large main neath the hall of the stairway, to prevent tank water

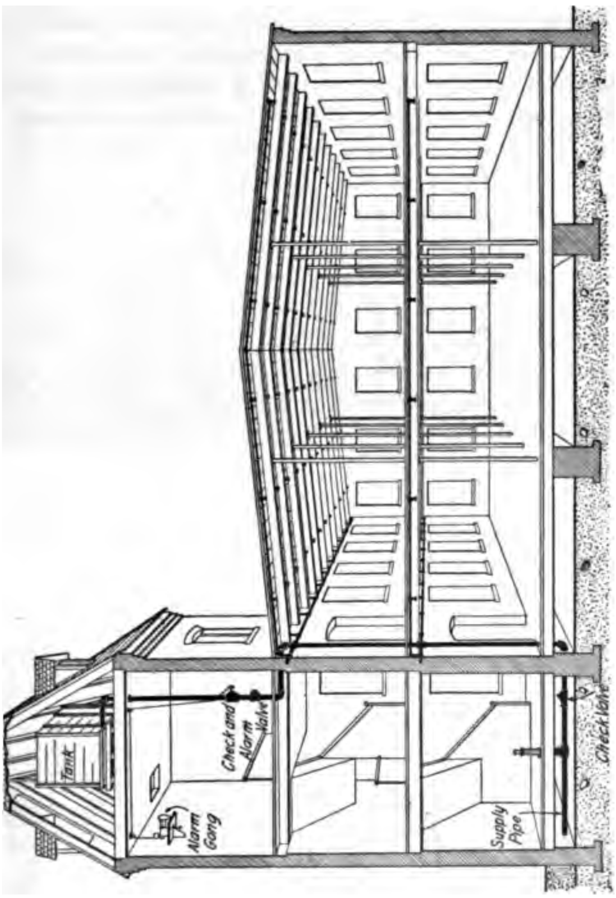


FIG. 27

going back to the main should the pressure in the main time be reduced, and there is a check-valve on the supply line in the room under the tank, to prevent the water from rising up and overflowing the tank.

The tank can be filled and kept full with an ordinary ball-cock, which is supplied by a small branch pipe taken from the street-service pipe. In combination with the stand pipe is an automatic alarm attachment that rings a gong when the water begins to flow to the sprinklers. The system of piping in the mill shown in Fig. 27 does not require detailed description. The drawing shows the sprinklers arranged along the ceiling, and the branch pipes running to supply the sprinklers. The apparatus shown in Fig. 27 is known as a *wet system*, because the water pressure is on the sprinklers all the time. The *dry-pipe system* is one in which water is turned on the main pipes, which supply the pipes in the building, but an air pressure is pumped up in the pipes inside the building greater than the water pressure. This air keeps the check-valves, previously mentioned, closed and prevents the water from filling the distributing pipes. When a sprinkler is open, however, the air in the pipe system immediately begins to escape. The air pressure is thus lowered and water automatically flows into the system and escapes through the open sprinklers, which are directly over the fire. The dry system is only desirable in places where wet pipes will freeze, because a considerable amount of valuable time is lost while the air blows from the sprinklers, which occurs before the water comes.

52. The general Underwriters' requirements, for proper installation of sprinkler systems, enforce the use of two independent water supplies, in order to secure the minimum rate of insurance, which may be from 30 to 50 per cent. reduction on the total insurance rates. One of these supplies must be automatic, and one should furnish water under heavy pressure.

The Underwriters accept the following combinations: Public waterworks and duplex steam pump; public waterworks and air-pressure tanks; elevated gravity tank and duplex steam pump; public waterworks and elevated gravity tank; public waterworks and rotary pump; elevated gravity tank and air-pressure tank; elevated gravity tank and rotary pumps.

In most of the foregoing combinations it might be possible to substitute the air-pressure tank in lieu of the gravity tank. The choice of these supplies is determined by the Underwriters.

53. Fig. 28 shows an Underwriter steam fire-pump with connections, which are self-explanatory. This pump should be so located as to be easily accessible and safe from damage by fire or other causes, and to take water from a reservoir or other source capable of supplying the pump for at least

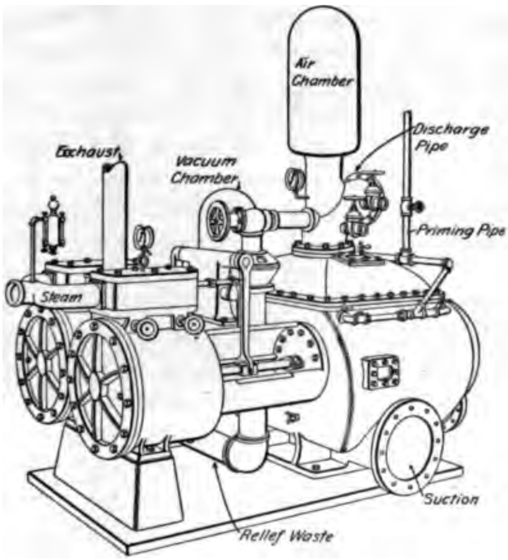


FIG. 28

1 hour; the suction pipe should have a strainer, foot-valve, and priming pipe when there is over 5 feet lift. A steam pressure of not less than 50 pounds per square inch should be maintained at all times, and an automatic regulator should be applied to the steam pump, so that it will start automatically when a sprinkler is unsealed, furnishing the system with a full supply of water. This is especially desirable where the other source of supply is an elevated tank that affords but a limited supply at a moderate or low pressure.

Fire-pumps built according to the "Underwriters' Pump" specifications of the Associated Factory Mutual Insurance Companies, dated May 20, 1893, have given the best satisfaction and are recommended.

The 500-gallon pump, which is 10 in. × 7 in. × 12 in. (ordinary size for small mills), has 8-inch suction, 6-inch discharge, 3-inch steam, 4-inch exhaust, and 2-inch hose outlets.

The 750-gallon pump, which is 16 in. × 9 in. × 12 in. (ordinary size for general use), has 10-inch suction, 7-inch discharge, $3\frac{1}{2}$-inch steam, 4-inch exhaust, and 3-inch hose outlets.

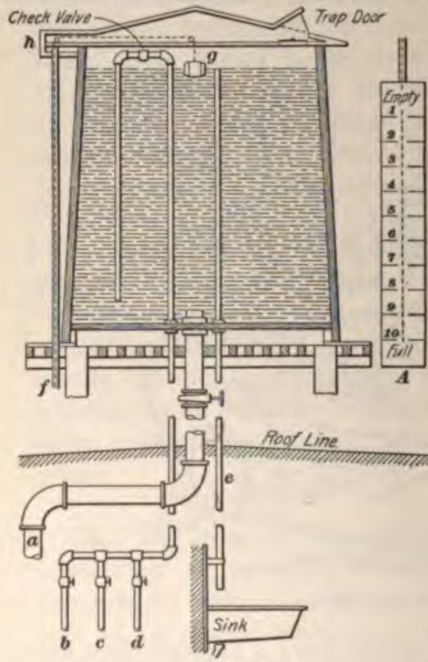


FIG. 29

The 1,000-gallon pump, 18 in. × 10 in. × 12 in. (usual size for large factories), has 12-inch suction, 8-inch discharge, 4-inch steam, 5-inch exhaust, and 4-inch hose outlets.

Before installing either a steam or a rotary pump, care must be exercised to furnish an ample supply of water for same, sufficient to run the pump at its rated capacity for at least 1 hour. The capacity of pumps should in all cases be determined by the Underwriters in jurisdiction. For a sprinkler system, no pump should be approved having a capacity less than 500 gallons per minute. It is required, where steam pumps are used, that there shall at all times be 50 pounds or more of steam pressure on the boilers. The steam pumps should be located in an independent building, so that they may be accessible in case of fire in the main building.

) is a detail drawing of a gravity supply tank, e above the roof of a mill, and connected up rinkler system. The pipe *a* is a main pipe going down to supply the sprinklers. It has a spring joint in the top story, just under the roof line, and a gate valve above the roof, located in a box, carefully covered with hair felt, to prevent freezing. The pipe *b* is a filling pipe for the tank. A check-valve is located on top of this pipe above the water-line, as shown, to prevent the tank water from being siphoned back to pipe *b* should this pipe be emptied. The pipe *c* is a live steam connection to blow steam into the tank and heat the water, when necessary, to prevent its freezing. The pipe *d* is a drip for the filling pipe, which should discharge openly into a sink. The valves shown on *b*, *c*, and *d* should, for convenience, be located in the engine room or first story of the building. The pipe *e* is an overflow to the tank. It should discharge openly into a sink that can be seen by the engineer when he stands at the valve on the pipe *b*. The pipe *f* is ¾ inch. It is continued straight down from the top of the tank to the indicator in the first story (a detail of the indicator is shown at *A*), and a chain passing through the pipe *f* connects the float *g* in the tank to a indicator board. The chain moves over two the top of the tank, as shown. The indicator be located in full view of the engineer at his

Fig. 30

work, and in such a position that he can pull down the indicator occasionally and see that it is in working order. At *h* is constructed a boxing to protect the pulleys from the weather.

55. Air-pressure tanks should be constructed according to the Underwriters' rules and their capacities determined by the Underwriters. These tanks should be located in the upper story of the building and must be kept two-thirds full of water and an air pressure maintained (never less than 75 pounds) that will give not less than 15 pounds pressure on the highest line of sprinklers when all water has been discharged from the tank. Fig. 30 shows a side elevation at *A* and an end elevation at *B* of an air-pressure tank of approved make. There is only one pipe opening into this tank, which is shown at *a*. A water gauge and a pressure gauge are shown connected to the end of the tank, with try cocks and blow-off drips, which are necessary for the engineer to blow through occasionally to see that the gauges are in good working condition. To maintain the required air pressure, various devices may be utilized, depending on the power available. Fig. 31 shows the different pressures and the different quantities of water in pressure tanks at the different water levels, which is a good thing for engineers to know.

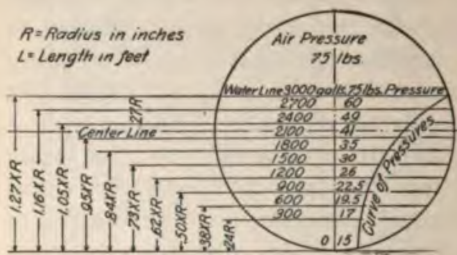


FIG. 31

PIPING

56. The sizes of pipes for a sprinkler system will in all cases be determined by the Underwriters having jurisdiction. In December, 1896, at a meeting of the Underwriters, held in New York City, a committee was appointed to deal with the subject of automatic sprinkler installations, and establish

niform rules for the same. The result of their work is indi-
ated in the third and fourth columns of the following table:

NUMBER OF SPRINKLERS ALLOWED ON A GIVEN SIZE OF PIPE

Size of Pipe	Number of Sprinklers Allowed		
	Main Pipes		Branch Pipes
	Associated Factory Mutual Insurance Companies	National Board of Fire Underwriters	National Board of Fire Underwriters
3/4	1	1	1
1	2	2	2
1 1/4	3	4	4
1 1/2	5	8	6
2	10	16	8
2 1/2	20	28	16
3	36	48	28
3 1/2	55	78	
4	80	110	
4 1/2	110		
5	140	150	
6	200	200	

It was also determined that for "branch lines" where more han six sprinklers are on one branch line, after passing the ixth sprinkler, the pipe schedule shall apply to the next arger size of piping.

It was also concluded that no feeder to any such branch ine shall be smaller than said branch line. Also that not nore than six sprinklers shall be placed on one branch line f pipe, except under special regulations as to pipe sizes as er above schedule.

When the sprinklers required on any one floor exceed the umber allowed to a 6-inch pipe, then a number of supply ipes are used, either 4-inch, 5-inch, or 6-inch pipes. There

can be no definite rule for the size or number of supply pipes or for any of the details of the sprinkler installation.

Reliable equipments can be had only by carefully planning each equipment in accordance with the building to be pro-

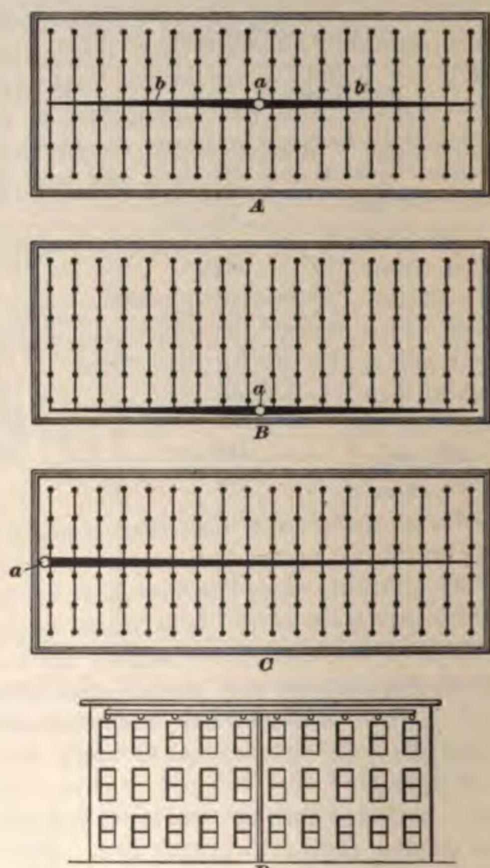


Fig. 32

tected and the available water supply. The Underwriters' schedules must be strictly adhered to by the constructing engineer, except where special permission is granted by the Underwriters to make changes. The size of the risers is

ed by the number of sprinklers required on any one
the building or in any section divided by fire-walls.
ir, or elevator towers that have openings in floors
e treated as one room, and the pipe sizes arranged
gly. In no case must risers or supply pipes for
systems be tapped for domestic purposes because
ulation of water in the pipes greatly adds to the
of sediment.

At *A*, Fig. 32, is shown the center central-feed
of piping to the sprinklers. It consists of a central
he automatic sprinklers, the riser being at *a* and the
rizontal distributing lines being at *c c*, which are
or reduced as they run from the main riser. At *B*
is shown a side central feed to the automatic sprin-
e riser being at *a* and running against one of the walls
the building. At *C*, Fig. 32, is shown an end central
tem of distribution. The riser *a* is run up against
wall of the building. The best method of piping a
ilding for water distribution to sprinklers [illegible]

[illegible]

building.

STEAM-HEATING PIPE SYSTEMS

(PART 1)

GRAVITY CIRCULATING APPARATUS

FUNDAMENTAL PRINCIPLES

DEFINITIONS

1. Steam-heating pipe systems wherein the water of condensation is returned to the boiler by gravity are known to the steam-heating trade as **gravity circulating apparatus.** When properly installed, they heat with safety and economy, and are noiseless and easily managed. The element of economy is secured by returning to the boiler, for reevaporation into steam, the water of condensation from the radiators or other heating surfaces. No heat is wasted, the condensation returning to the boiler at a temperature of, say, 180°, after the steam and water of condensation have given off practically 1,000 British thermal units per pound in warming the air in the various rooms of the building.

Pipes that serve to convey steam from the boiler or other source of supply and to distribute it to several branches, are known as **steam mains.** They are usually run along the cellar ceiling, being hung from the first-floor beams by adjustable iron hangers. They pitch downwards from the highest point near the boiler to the lowest point at the farther end of the mains. The pitch should be at least

¼ inch in 10 feet, so that the water of condensation may freely flow to the lower end of the main.

An **overhead main** is a steam main that is run horizontally, or nearly so, at an elevation higher than the radiators that it supplies, and is supplied from the boiler by a vertical **rising main.**

Risers are vertical pipes that rise from floor to floor to convey steam from the steam main to the radiators or coils on the several floors. **Drop risers** are those in which the steam flows downwards to the radiators or coils from a steam main above, usually in the attic.

A **return main** is a nearly horizontal line of pipe that receives all water of condensation from the heating system and returns it to the boiler or otherwise disposes of it. It is usually run near or under the cellar floor.

A **dry return main** is one that is run above the water-line of the boiler and, consequently, is partly filled with steam.

A **wet return main** is one that is run below the water-line and is filled with water at all times. As a rule, this is more reliable than a dry return main except in places where the main is subject to frost.

Return risers are those vertical pipes that take the water of condensation from the radiators or coils on the several floors of a building and convey it to the return main.

A **drip pipe, relief,** or **bleeder** is a small pipe used to drain water of condensation away from the foot of risers or from a low point, pocket, or trap in the main steam pipes. In running steam mains, it is common practice to connect relief or drip pipes to the main at points where a reduction in the size occurs, and ordinary reducing fittings are used. This serves to prevent water hammer by relieving the main of condensation at points where it would otherwise accumulate. By using eccentric fittings, however, so as to bring the bottom of the main into line throughout its length, the use of many bleeders, or drip pipes, may be obviated. In any case, a relief pipe should be connected to the extreme end of the main to drain the water of condensation into the main return.

STEAM AS A HEATING AGENT

2. By experiment it has been found that if water is heated to its boiling point of 212° F. under a constant pressure of 14.7 pounds per square inch, or atmospheric pressure, it will require about 966 British thermal units of heat to change it into steam of the same temperature. The amount of heat necessary to convert water into a gas, or rather vapor, of the same temperature and pressure, is called its **latent heat of vaporization,** or, simply, the **latent heat of steam.** This heat cannot be detected by the thermometer.

The latent heat of steam is taken advantage of in the warming of buildings by simply allowing the steam to condense in suitable coils or radiators, provision being made for draining the water of condensation from them. For every pound of steam condensed in a radiator, or, for every pound of water formed by the condensation, 966 British thermal units of heat must be transmitted from the surface of the radiator to the air and surrounding objects of the room. The water of condensation will be of the same temperature as the steam so long as its heat is not transmitted to the surrounding air.

3. The comparative value of steam as a heating agent varies greatly with its condition, whether wet, dry, or superheated, and also with its pressure, whether high or low. The steam serves principally as a transmitter of heat from the boiler to the radiators; and to perform this function to the best advantage it should contain the greatest practicable amount of heat per cubic foot.

Wet steam, a term applied to steam in which water in finely divided particles is held in suspension, contains less heat per pound, and also per cubic foot, than dry or normal steam; therefore, a larger volume and weight of steam will be required to transmit a given amount of heat when wet than when dry. It also produces more water in condensing, and the liability to trouble from water hammer is much greater.

Low-pressure steam contains less heat than high-pressure steam, when measured by the pound, but the difference is enormously greater when they are compared by the cubic foot. Thus, steam at 10 pounds absolute pressure contains 1,172.89 British thermal units per pound and 31 British thermal units per cubic foot, has a temperature of 193.28°, and 1 pound has a volume of 37.83 cubic feet. Steam at 74 pounds absolute pressure contains 1,207.43 British thermal units per pound and 209.3 British thermal units per cubic foot, has a temperature of 306.52°, and 1 pound has a volume of 5.767 cubic feet. Comparing steam at the two pressures, it is seen that for a difference of 64 pounds in pressure the high-pressure steam contains 34.54 British thermal units more than the low-pressure steam per pound, 178.3 British thermal units more per cubic foot, has a temperature greater by 113.24°, and a volume smaller by 32.063 cubic feet.

It will be seen that the quantities of heat contained per cubic foot are in the proportion of about 1 to 7, and that this ratio is nearly the same as that between the absolute pressures. Therefore, the volume of steam that must be moved through the pipes and radiators, in order to transmit a given amount of heat, is much greater at low than at high pressures.

The radiators also must have a greater area of emitting surface, because the temperature of the low-pressure steam is so much lower. Thus, in the case given, if the radiators were used to heat air having an average temperature of 55°, they would emit heat in the following proportion:

$$(306.52 - 55 = 251.52) : (193.28 - 55 = 138.28) = 1.8:1;$$

therefore, to do equal work, the low-pressure radiators would require about 80 per cent. more emitting surface than the high-pressure radiators.

STEAM DISTRIBUTION

4. Methods of Steam Distribution.—In all systems of steam heating, the flow or distribution of the heating medium is brought about by its condensation within the

heat-radiating surfaces, the slight reduction in pressure due to condensation causing the steam to flow from the boiler or other relatively high-pressure source of supply to the radiators. In other words, the flow of steam is induced by a difference of pressure between that at the source of supply and that at the point of utilization. The steam is conveyed from the boiler through a system of main pipes running along the cellar ceiling and suspended so as to have a downward pitch from the boiler, to provide drainage for water of condensation. The distribution of steam from the main pipes to the radiators is effected by the risers, in which the flow of steam from floor to floor is usually upwards, but in some cases both the steam and water of condensation flow downwards from overhead mains in the attic, the vertical distributing lines in such cases being known as drop risers. Sometimes the water of condensation from radiators and coils flows downwards to the main return pipes through the same risers that serve to supply the steam, the water and steam flowing in contrary directions. Other systems of piping provide for the return of the water of condensation through separate lines of pipe known as return risers, which are connected by branch lines to the main return in the basement. When the steam and water of condensation flow together in the same direction in the same pipe, the steam is likely to be very wet, the separation of water and steam being less complete than when they are kept apart by separate pipes. When the currents flow in contrary directions in the same pipe the wetness of the steam in aggravated, and there is such an amount of mechanical interference between them that larger pipes are required than would otherwise be necessary. There is also much greater liability to water hammer and sizzling noises. The main returns—in fact, all return pipes—serve merely to convey water of condensation back to the boiler to be reevaporated into steam and therefore do not, as in hot-water heating, provide what might rightly be termed a complete or continuous circuit for the heating medium, which, in the case of steam heating, is changed by condensation from a gaseous to a liquid condition.

A steam-heating system will work perfectly without a return, provided that the water of condensation is drained from the apparatus. Whether this water should be returned to the boiler, or be thrown away, is merely a question of economy, and does not affect the supply of steam to the radiators. The water of condensation contains a considerable amount of heat, which may be saved by returning it to the boiler. It is also clean and pure, and therefore much better for steam making than ordinary fresh feedwater.

Apart from the tendency toward an appreciable reduction of pressure due to condensation, the difference between the pressures existing at various radiators and the boiler is due to the resistance that is offered by the supply pipes to the flow of steam through them. If this resistance could be completely abolished, the steam would flow instantaneously to any point where the pressure was lowered. Thus the pressure would be perfectly and continually equalized throughout the whole system. A considerable fall of pressure cannot occur at any point unless the flow of steam to it is in some way obstructed.

5. Principle of Steam Circulation.—Suppose that a vessel *a* partly filled with water is placed over a fire *b*, as shown in Fig. 1, and connected to a pipe loop *c d e f*. If the water is boiled in *a* and part of it is converted into steam, the steam forming in the steam space of *a* will increase the pressure within it, and will compress the air in the pipes *c*, *d*, and *e* so that the air pressure in *e* will equal the steam pressure in *a*. Since these pressures are equal, the water-line in *e* will be level with the water-line in *a*. These water-lines will be level at all pressures so long as the pressures on them are equal. If a cock or valve is attached to the pipe *e* above the water-line, and the air is allowed to be forced out of the system by steam filling the pipes *c*, *d*, and *e*, the water-line in *e* will rise slightly because the pressure on it will be slightly less. This is due to the fact that a part of the steam in *d* and *e* becomes condensed and a certain pressure is required to cause a flow of steam to supply this loss. This

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

up by the water. If not allowed to escape through air vents, this air will accumulate in the radiators and thereby decrease their heat-radiating power by preventing the steam from reaching the heating surface. If, in the process of evaporation, the air were driven off from the steam and the radiators were sealed so the air could not return, a vacuum would be formed by the condensation of the steam due to the cooling of the radiator or shutting off the supply of steam thereto. Fig. 2 shows a radiator with a sealed return pipe and a valve in the steam connection at *a*, a check-valve being placed at *b*, and an air valve at *c*. If steam is admitted to the radiator, through *a*, the air is discharged through the air valve at *c*, the condensation will flow through *b*, and the radiator will give off some of the heat of the steam generated by the boiler. Now, if the air valve is closed and the supply of steam is shut off at *a*, the water from the steam condensed by the radiator will accumulate above the check-valve in the return pipe, and, as the radiator cools, the water thus accumulated will continue to give off heat until the radiator and water cool to the temperature of the surrounding atmosphere, when a gauge placed at *d* will register the pressure in the radiator as below that of the atmosphere. On opening the cock *c*, air will rush into the radiator, in which the pressure will become that of the atmosphere, and the water in the return pipe will drain through the check-valve. By removing the check-valve and repeating the operation, it will be found that the water in the return pipe will rise as the radiator is cooled. If the height of the return pipe is not sufficient to give a column of water whose hydrostatic pressure is equal to the amount to which the pressure in the radiator is reduced

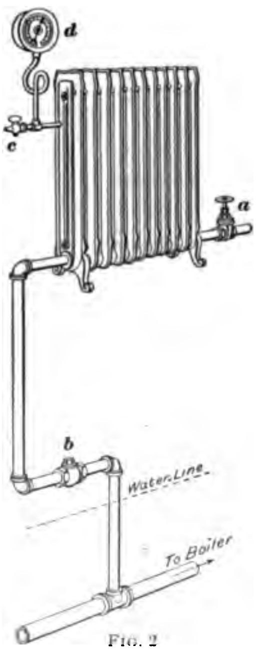


FIG. 2

below that of the atmosphere, the water will back up into the radiator until an equilibrium of pressures is established. Opening the cock *c* allows the water to fall through the return pipe again. From this explanation it becomes apparent that air valves serve to prevent the air from obstructing the circulation of steam.

DESIGN OF PIPING SYSTEMS

CLASSIFICATION OF SYSTEMS

7. Considered with reference to the element of pressure alone, steam-heating systems are divided into two classes: (1) those that are operated under a pressure greater than 10 pounds by the gauge are known as **high-pressure systems**; (2) those that are operated between atmospheric pressure and 10 pounds gauge pressure are known as **low-pressure systems**. The latter class of systems is the one in most common use.

With the high-pressure system of heating, less radiating surface is required, and the piping may, in some cases, be made one size smaller than for pressures of from 2 to 5 pounds; the fall of pressure that may be permitted at the radiators is, however, no greater than in a low-pressure system; hence, the size of the piping can be reduced but little. The high-pressure heating system, which is sometimes employed in factories and workshops, requires a better, and hence more costly, class of steam generators than are commonly employed in low-pressure heating, and the radiators also require to be made extra strong. High-pressure heating is not recommended for domestic work.

8. Viewed solely from the standpoint of the circulation of the heating medium, steam-heating systems may be classified under two general divisions: (1) those in which the water of condensation from radiators and coils flows back to the boiler by gravity are known as **gravity return systems**; (2) those in which the water of condensation is forced back to the boiler from the return mains of the heating system by

a pump, steam loop, steam return trap, or other such appliance are known as **forced return systems.** Both systems may have wet or dry returns.

The gravity return system is used where the full boiler pressure is carried on the heating system. It cannot be used elsewhere. The forced return system is used when the boiler pressure is higher than the pressure in the heating system, as, for example, when a pressure-reducing valve is used on the live steam-supply pipe to the heating system.

GENERAL PRINCIPLES OF DESIGN

9. In planning any system of steam pipes, there are two things to be kept always in mind and that must be fully provided for; these are drainage and the movement of the pipes by expansion or contraction. No heating can be done without condensation, and the water thus produced must be disposed of promptly and completely and in a manner that will prevent interference with the steam supply.

Expansion and contraction are inevitable, and the movement due thereto is repeated every time the system undergoes any considerable change in temperature. This movement must be provided for, otherwise it will break the joints and make serious trouble.

10. Saturated steam will part with its heat only by condensation. No matter how small the amount of heat emitted, a corresponding amount of condensation must take place. If the amount of condensation is small, the water may remain suspended in the steam, making the steam wet; but if the amount is considerable, it will collect and flow or drain toward low points. All pipes that supply steam must be carefully graded, that is, inclined so that the water will flow by gravity in the proper direction. Care must be taken to avoid the formation of pockets, or depressions, in which water may collect. Return pipes should also be inclined so as to discharge the water by gravity into the drip pipes, and should also be free from depressions, or pockets.

The downward grade given to return pipes should be as nearly uniform as practicable. There should be no upward bends or loops, because air is likely to collect in them and impede the flow of the water.

When the returns are connected to a main that is located above the water level, and if there is any perceptible difference in the pressures at the various radiators thus connected, the steam will flow backwards through the return pipes toward the points of lowest pressure, and thus interfere with the drainage and cause water hammer.

11. The hammering noises frequently heard in steam pipes are caused by the violent collision of bodies of water, either with each other, or with the elbows and other fittings that change the direction of the flow, or with the end of the pipe or chamber.

When water is carried through a pipe by a current of steam, the water has a tendency to form into slugs which fill the bore of the pipe and move along like pistons. When there is a lower pressure in front of one of these slugs, the pressure behind the slug drives it forwards at high velocity, so that when it strikes an obstruction the impact produces a loud noise.

It is sometimes quite difficult to locate the point where water hammer occurs, owing to the fact that metal pipes are good conductors of sound and transmit shock and vibration over long distances. Sound is very deceptive, because vibrations may travel a great distance along a pipe muffled at the point where water hammer occurs, and will come out loud and clear at some point where the pipe is exposed.

12. Points at which an unusual quantity of water can collect in a piping system are called **water pockets**, and are very dangerous in pipes through which steam flows at high velocity. Ordinarily the water will accumulate quietly until the pocket is full, when the current will suddenly pick up a part of the water, sometimes all of it, and carry it forwards in a compact mass. The body of water moves with the

same velocity as the steam, and when it arrives at an elbow or T, where the direction of the flow is changed abruptly, it strikes the fitting like a projectile, and the blow is often sufficient to crack the fitting, or even break it.

A water pocket in a steam pipe that supplies an engine is particularly dangerous, because the water is liable to go over into the cylinder in a flood. This usually results in a smash up, because the engine is not provided with a drainage apparatus of sufficient size to handle so much water.

ARRANGEMENT OF RETURNS

13. There are two classes of return mains, those of the first class being known as **dry return mains,** or those that are run above the boiler water-line; those of the second class are known as **wet return mains,** or those that are run below the water-line of the boiler.

The wet return mains being constantly below the boiler water level, must, of necessity, in all gravity return systems, that is to say, all systems in which the force of gravity alone is relied on to return water of condensation to the boiler, be always filled with water. By this system of return, all branch return mains, riser returns, and bleeders, or other relief pipes, join the main return below the water-line.

Two leading objections to the dry return-main system are:

1. If branches join it direct, that is, without being trapped, the steam or air, or both, in the return main will flow toward areas of lower pressure, and air or water, or both, in the returns may thereby become locked in parts of the heating system where it is undesirable to have it.

2. If the steam distributing lines are not properly proportioned to the demand for steam at the radiators, or should the resistance, frictional or otherwise, to the flow of steam from the boiler to the radiators be so great as to cause a difference between the boiler pressure and the return-main pressure sufficient to sustain a column of hot water whose height is greater than the vertical distance between the return main and the boiler water-line, the water in the boiler will

be backed up in the returns, and the boiler water-line, as shown by a perfect water gauge, will fall correspondingly.

14. For the purpose of illustrating the principle underlying the operation of the wet and dry return systems of steam heating, a wall coil *a* may be fitted up and connected to a small steam generator or heater set over an ordinary fire-pot *d*, as shown in Fig. 3. Water is poured into the heater, through the safety valve *c*, to the height shown by the dotted line at *b*, that is, to the boiler water-line; a char-

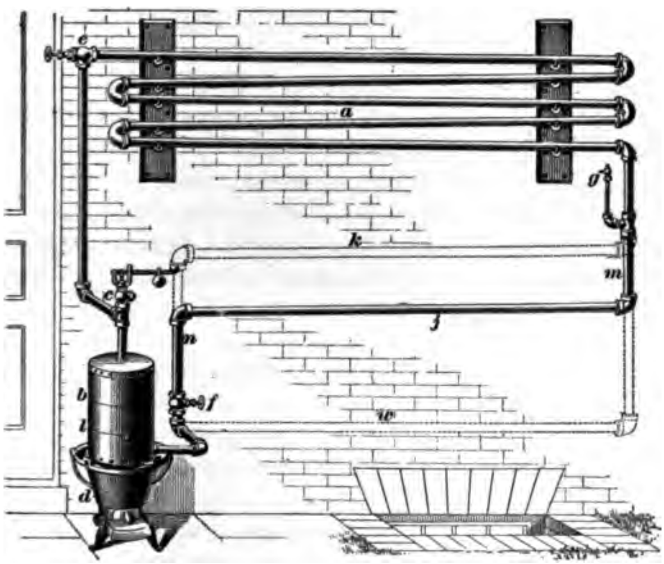


FIG. 3

coal fire is then started in the fire-pot *d*. An angle valve *e* is screwed on the steam pipe and joins it to the pipe coil, and a straight globe valve *f* is screwed on the return pipe below the boiler water-line *b*; both valves are open. A pet-cock *g* is attached on top of a branch taken from the return pipe above the boiler water-line and near the coil; this cock, however, is closed.

Since the boiler and the piping are hermetically sealed, the pressure within the apparatus will soon become greater

than that of the atmosphere, steam will be generated, the air in the apparatus will be compressed in the pipe coil *a* and return pipe *j*, and the water-line in the return pipe will remain practically unchanged, that is, it will remain level with that in the boiler.

Now partly open the petcock *g* to allow the air in the coil to escape freely to the atmosphere, and as soon as steam blows through, close it again; the water-line in the return pipe will be slightly higher than *b*, the height varying with the rapidity of condensation of steam in the coil and the resistance offered to the flow; suppose that it has risen to the line *n*, which is called the *minimum water-line*, that is, the water level while the coil is condensing steam under ordinary conditions. It will also be observed that the water in the boiler, should a gauge glass be attached, remains practically the same. This is because the water displaced from the boiler in forming the head in the return pipe is so small that the loss of depth in the boiler to compensate for the displacement is so slight as to be practically out of consideration. The return pipe *j*, then, is a *dry return* because it is not *filled* with water.

Suppose that the rapidity of condensation of the steam is now increased by throwing a spray of water on the coil, thereby causing the steam to flow so rapidly from the boiler to the coil as to cause a difference between the pressure in the boiler and in the return pipe sufficient to back water up the returns, say, to the point *m*, to balance the boiler pressure; it will be found that the water in the boiler rapidly descends to, say, the line *l*. The cause of this is simply that the boiler water backs up the return pipe, a large quantity of water being required to fill the nearly horizontal pipe *j*. This volume of water is practically useless as far as the pressure due to the head between *m* and *l* is concerned. This new water-line *m* in the return pipe is called the *maximum water-line*. The water-line *m* can easily be formed without pouring water over the coil, by partly closing the steam valve *e*.

In nearly all steam-heating plants there is a varying water-line in the return pipes, and since the water-line is

variable, it follows that every steam-heating apparatus has a high and a low water-line. The low water-line is obtained when the apparatus is run during mild or moderate weather, and the high water-line when all radiators are condensing steam to their full capacity, as when zero weather prevails.

In order to avoid loss of water in boilers by return mains being filled when the pressure comes on, the mains should either be run above the maximum water-line or below the boiler water-line. They will then be constantly dry return mains or wet return mains, as the case may be, and the boiler water-line will remain constant.

15. Many house-heating boilers have changing water-lines, the cause of which can usually be traced to the arrangement of the returns, combined with steam pipes too small to do the work easily.

The loss of water from a steam boiler is a very serious matter, because plates and castings that should be below the water-line become exposed to the intense heat of the fire and are liable to either bulge or crack; or, still worse, if water is run into the boiler to compensate for that lost, the possible sudden conversion of the water into steam might increase the boiler pressure so rapidly as to burst the boiler. The best practice is to discard dry returns unless they are run permanently and positively above the maximum water level, as shown by the dotted lines at k, Fig. 3.

Where practicable, wet returns should always be run as shown by dotted lines at w, Fig. 3, and any rising of water in the returns should take place in vertical pipes only.

When return branches, such as radiator returns, relief pipes, etc., join into a dry return main, disagreeable noises are sometimes heard. The noises are due to the fact that steam flows through the returns toward those points of the system that are subject to the lowest pressures, and in doing so, the direction of its flow is often contrary to the flow of the condensation water. The water then is backed up in some of the returns and water hammer often results.

16. Fig. 4 shows a boiler *A* set on a floor about 5 feet below the level of the cellar floor *B*. The steam main *a*, to the top of which the riser connections *b*, etc. are joined, is suspended from the floorbeams above; it has a downward pitch from the boiler to the relay *r*, and then to the extreme ends *c* and *d*. The return risers *e* and relief pipe *f*, etc. join the dry return main *g*. In this particular case, the returns are all run above the boiler water-line to avoid excavating a long deep trench under the floor of the cellar *B*.

Suppose, now, that the piping is not properly proportioned; that, in fact, the steam main or some of its branches are too small to furnish steam at the proper pressure to a certain

FIG. 4

line of radiators. It will readily be seen that steam or air or both combined, which may be in the return main *g*, will flow into the radiators so supplied, they being then subjected to a pressure lower than that in *g*. Such radiators will then have two steam inlets and no outlets, if they are connected up on the two-pipe system, and water of condensation will consequently gather in them. If, however, they are connected up on the one-pipe system, the steam or air, or both, that flows through the nearly horizontal return pipe that is supposed to drain the risers into the return main, may, by flowing against the water of condensation, back it up in the pipes and thus cause disagreeable noises.

There are many different ways of overcoming this difficulty; the most simple, probably, being that of forming an inverted loop on the return main, as shown by dotted lines at *i*. This will cause the water of condensation to fill the return main *g* and the lower ends of all the vertical returns and relief pipes, so that no steam can enter the radiators other than that passing through the main steam pipe and its branches. To prevent the water in *g* from being siphoned into the boiler by water flowing down the pipe *j*, which actually forms the long leg of a siphon, a pressure-equalizing pipe *k* connects the top of the loop to the steam main. The results obtained by the use of an inverted loop, as at *i*, are equivalent to those that would be obtained if the boiler were raised to such a height that its water-line would be level with the loop. Better results, however, would be had if the return main and its branches were sunk below the water-line of the boiler, and smaller pipes could be employed in the system.

17. Many fitters favor the use of the wet return in preference to the dry return, but excellent results are obtained with the latter when the system is properly installed and is so arranged that there are no pockets in which water may accumulate. The dry return is especially adapted for use in cellars where there is plenty of head-room, and where there is not, the main return may be carried around the cellar on the side walls. The wet return system has the disadvantage that the volume of water in the system is greater, requiring a longer time to get up a complete circulation of steam. Under some conditions in the wet return the water of condensation flows up from drip connections at the foot of return risers into the main steam pipe. When the pressure in the piping system is properly balanced, that is, when the pressure in main and return pipes is practically the same, the steam will circulate readily and the water of condensation will flow along the bottom of a dry return main without filling it completely. With the dry return system, the main return piping should be one size larger than corresponding

horizontal piping of the wet return system, but the return risers for the former system may be one size smaller than for the latter. Some fitters do not consider that water seals assist the circulation of the heating medium in balanced systems, when the steam is carried at or not much above atmospheric pressure. They claim that such seals do not prevent the water of condensation from backing up into the steam main in case the pressure on the return side becomes temporarily greater, as may be the case when the valve to a cold radiator is suddenly opened. As the fall of pressure at any radiator, apart from that due to condensation, is due to the resistance that the supply pipes offer the flow of steam, it follows that trouble from water backing up into radiator drip pipes may be remedied by increasing the diameter of the supply pipes. It is quite impracticable to connect return pipes from radiators with a dry return main where a considerable difference in pressure exists between them.

When the return main is located below the water level, the water that it contains prevents the passage of steam from one return to another, and thus the steam is compelled to pass through the system in the direction it was intended to go, instead of making a short circuit or by-pass. The difference in water-lines in return pipes varies in the several returns. The hot water rises about 29 inches for each pound of difference in pressure, until it balances the difference in pressure. Thus, a radiator that is well above the proper water-line may be flooded by water backing up if there is a water pocket near it in the return.

SIZES OF PIPING

18. General Considerations.—The size of steam piping for a given purpose depends on several factors, among which are the steam pressure, the length of the pipe, and the frictional resistance offered by the line of pipe and the fittings. All these factors, including also the diameter of the pipe, influence the velocity with which the steam flows through the piping and hence the amount of steam that

might be delivered in a given time; in fact, the flow of steam in pipes is affected by so many varying conditions that the formulation of accurate rules, general in application, for determining the requisite size of piping for heating systems is impracticable. Besides, rules taking into consideration all the surrounding conditions would, in any case, give only approximations to the correct results, since some of the factors must be assumed. Wide practical experience is required in order to give the right value to some of the coefficients that affect the proper solution of the problem, and hence it is deemed advisable to present in tabular form the pipe sizes that have given good results in practice, in addition to a simple empirical rule.

Steam-heating mains should be proportioned according to the pressure to be carried, the distance to which the steam is to be transmitted, the drop in pressure desired, and the amount of radiating surface to be supplied. They are commonly reduced in size toward the end of the main as branches therefrom are taken off. Some pipe fitters decrease the size of mains in proportion to the decrease in the combined area of the branches to be supplied, but this is not regarded as being the best practice, as the reduction should be more gradual. It is sometimes specified that the main near the boiler shall have an area equal to the aggregate area of all its branches.

The frictional resistance to the flow of steam increases with the length of the pipe, the quantity of steam delivered being correspondingly diminished. Approximately, it varies inversely as the square of the velocity; that is, taking a velocity of 100 feet per second for example, and assuming the reduction in pressure in 100 feet of main to be about $1\frac{1}{2}$ pounds, with one-half of that velocity, or 50 feet per second, the reduction in pressure would be only one-fourth of $1\frac{1}{2}$ pounds, while with one-fourth the velocity, or 25 feet per second, there would be one-sixteenth of $1\frac{1}{2}$ pounds reduction in pressure.

In the design of extensive heating systems, such as are commonly found in public and semipublic buildings in large

cities, as well as in a great many state institutions, such as asylums and jails, it is essential that the length of the various pipes be carefully considered in determining their diameter previous to installation. Within the limits of reason, the larger the pipes the more satisfactory will be the results in heating, but considerations of economy and acceptable engineering practice should operate to prevent the use of pipes larger than are actually required.

19. Empirical Rule for Ordinary Residence Mains.—Under the conditions ordinarily found in low-pressure gravity residence heating systems, an adequate supply of steam can be obtained by allowing .7854 square inch in sectional area of the main for each 100 square feet of radiation to be supplied. Hence, the nominal area of a 1-inch pipe, .7854 square inch, may be taken as a factor in calculating the size of main required to supply a given amount of radiation in ordinary residences, where the mains are usually short. For an actual case .8 may be used instead of .7854 to simplify calculations. This factor applies to mains larger than 2 inches and makes allowance for loss by condensation in the mains. For smaller mains, 1 square inch of sectional area should be allowed for each 100 square feet of direct radiation to be supplied.

EXAMPLE.—What size of main is required in an ordinary residence to supply 350 square feet of direct radiation?

SOLUTION.— $\frac{350 \times .8}{100} = 2.8$ sq. in. As the sectional area of a $1\frac{1}{2}$-in. pipe is 2.038 sq. in., a $1\frac{1}{2}$-in. pipe is too small; and as the sectional area of a 2-in. pipe is 3.356 sq. in. a 2-in. pipe is a little too large; in order to be on the safe side the 2-in. pipe should be used. Ans.

The length of a pipe has a marked influence on its steam-carrying capacity; that is, with a pipe of a given size and the steam pressure at the inlet remaining the same, a long pipe will discharge less steam than a short pipe.

20. Sizes of Mains for Two-Pipe Systems and Direct Radiation.—The amount of radiation that can be supplied by steam mains of different sizes, 100 feet long, in a two-pipe

system, and with different steam pressures, is given in Table I, which is due to Mr. A. R. Wolff. In this table, it is assumed that 1 square foot of radiating surface will transmit 250 British thermal units per hour; hence, the values in

TABLE I

SIZES OF MAINS, DIRECT RADIATION, TWO-PIPE SYSTEM

Diameter of Supply Inches 100 Feet Long	Diameter of Return Inches 100 Feet Long	2 Pounds Pressure		5 Pounds Pressure	
		Total Heat Transmitted British Thermal Units	Direct Radiating Surface Square Feet	Total Heat Transmitted British Thermal Units	Direct Radiating Surface Square Feet
1	1	9,000	36	15,000	60
1¼	1	18,000	72	30,000	120
1½	1¼	30,000	120	50,000	200
2	1½	70,000	280	120,000	480
2½	2	132,000	528	220,000	880
3	2½	225,000	900	375,000	1,500
3½	2½	330,000	1,320	550,000	2,200
4	3	480,000	1,920	800,000	3,200
4½	3	690,000	2,760	1,150,000	4,600
5	3½	930,000	3,720	1,550,000	6,200
6	3½	1,500,000	6,000	2,500,000	10,000
7	4	2,250,000	9,000	3,750,000	15,000
8	4	3,200,000	12,800	5,400,000	21,600
9	4½	4,450,000	17,800	7,500,000	30,000
10	5	5,800,000	23,200	9,750,000	39,000
12	6	9,250,000	37,000	15,500,000	62,000
14	7	13,500,000	54,000	23,000,000	92,000
16	8	19,000,000	76,000	32,500,000	130,000

the columns headed Total Heat Transmitted, British Thermal Units are obtained by multiplying the values in the columns headed Direct Radiating Surface, Square Feet, by 250. The number of square feet of radiation that a pipe longer or

shorter than 100 feet will supply can be found by multiplying the number of square feet of radiation corresponding to the size of the pipe and taken from the table by a factor that is the square root of the quotient obtained by dividing 100 by the length of the main, in feet. In order to obviate the necessity of calculating the factor mentioned, its value for the lengths of main most often found in practice is given in Table II. The length of main to be used in this calculation of radiation is not its actual length, but the actual length corrected for obstructions by fittings, etc., and called the *equivalent length*. In low-pressure heating

TABLE II

FACTORS FOR MAINS

Length of Pipe, Feet	200	300	400	500	600	700	800	900	1,000
Factor	.71	.58	.5	.45	.41	.38	.35	.33	.32

apparatus the obstruction offered to the flow of steam by bends and fittings should be reckoned as being equivalent to increasing the length of the main by the following amounts: Right-angle elbow, 40 diameters; globe valve, 125 diameters; entrance to **T**, 60 diameters. Thus, if a main 3 inches in diameter has an actual length of 124 feet, and three elbows, two globe valves, and one **T**, its equivalent length would be $124 + 3 \times 40 \times \frac{3}{12} + 2 \times 125 \times \frac{3}{12} + 1 \times 60 \times \frac{3}{12} = 271.5$ feet.

The following examples show how Tables I and II may be used:

EXAMPLE 1.—What size of supply main is required to supply 850 square feet of direct radiation with steam at 5 pounds pressure, the equivalent length of the main, that is, including the resistance offered by fittings, being 100 feet?

SOLUTION.—In the right-hand column of Table I, the nearest numbers to 850 are 480 and 880. The number 880 is a little more than 850, but is much nearer to it than 480. Therefore, follow horizontally across the table from 880 to the corresponding size of pipe given in the left-hand column, which is $2\frac{1}{2}$ in. Ans.

EXAMPLE 2.—What size of supply main is required to supply 9,086 square feet of direct radiation with steam at 5 pounds pressure, the equivalent length of the main being 800 feet?

SOLUTION.—By referring to Table I, it is seen that 9,086 sq. ft. of direct radiation may be supplied by a 6-in. pipe 100 ft. long. But, as the length of the main is 800 ft., it follows that a larger pipe must be used. The next larger size is 7-in. pipe, which, if 100 ft. long, would supply 15,000 sq. ft. of direct radiation.

To determine what amount of radiation a 7-in. pipe 800 ft. long will supply, it is necessary to multiply 15,000 by .35, which is the factor, taken from Table II, for a main 800 ft. long. A 7-in. pipe 800 ft. long will supply 15,000 × .35 = 5,250 sq. ft. of direct radiation. This shows that a 7-in. main is too small; therefore, we try the next larger size of pipe in a similar manner, thus: 21,600 × .35 = 7,560 sq. ft. An 8-in. pipe is therefore too small. Now we try the 9-in. pipe. 30,000 × .35 = 10,500 sq. ft. This is somewhat larger than is actually required, but, being very near to the given amount of radiation, 9,086 sq. ft., the size of pipe capable of supplying 10,500 sq. ft., that is 9-in. pipe, should be used. Ans.

To compute the area required for a given amount of radiation supplied by a main of greater length than 100 feet, multiply the area of the pipe corresponding to the amount of radiation, as given in Table I, by the square root of the quotient obtained by dividing the length of the main in feet by 100.

EXAMPLE 3.—At 5 pounds pressure, with the two-pipe system, how large a main is necessary to supply 5,000 feet of radiation, the main being 400 feet long?

SOLUTION.—In the last column of Table I, it will be found that the amount of radiation nearest to 5,000 ft., viz., 4,600 ft., requires a main $4\frac{1}{2}$ in. in diameter. Dividing 400, the length of the main, by 100 and extracting the square root of the quotient gives a factor of 2, by which the area of the $4\frac{1}{2}$-in. pipe is to be multiplied to obtain the requisite area of a main 400 ft. long to supply 5,000 ft. of radiation; thus, 2 × 15.96 = 31.92 sq. in., to which the area of a 6-in. pipe most nearly corresponds. The correctness of the result thus obtained may be checked by multiplying the amount of radiation given in the last column of Table I, opposite the 6-in. pipe, viz., 10,000, by the factor given in Table II, for a main 400 ft. long; thus, 10,000 × .5 = 5,000 sq. ft., showing that the required main should be 6 in. in diameter. Ans.

EXAMPLE 4.—With steam at 2 pounds pressure, how large a main will be required to supply steam to 5,000 feet of radiation, the main being 700 feet long?

Solution.—Dividing the length of main by 100 and extracting the square root of the quotient, a factor of 2.65 is obtained, by which the area of a pipe corresponding to a diameter of about $5\frac{1}{2}$ in. must be multiplied to obtain the size of pipe required to meet the stated conditions. It will be noticed that Table I does not give the size of main for 5,000 ft. of radiation operated at 2 lb. pressure, but it is evident from the table that it would be about $5\frac{1}{2}$ in. Steam pipe of this diameter is not manufactured, and hence, taking the enclosed area of a circle $5\frac{1}{2}$ in. in diameter, viz., 21.76 sq. in., and multiplying by 2.65, $21.76 \times 2.65 = 57.66$ sq. in. is obtained. An 8-in. pipe has an internal area of 50.04 sq. in., while a 9-in. pipe has an area of 62.73 sq. in. It is therefore evident that an $8\frac{1}{2}$-in. pipe would be required, but since piping of that size is not manufactured, and it is better to err on the side of safety, a 9-in. pipe should be used. Ans.

21. Sizes of Mains for Indirect Radiation.—In estimating the sizes of pipes to supply indirect radiation that operate by natural draft only, it is customary to consider that 1 square foot of indirect radiation will condense as much steam as 2 square feet of direct radiation. Therefore Table I can be used, but the amount of indirect radiation must be doubled to find its equivalent in direct radiation.

Example.—What size of supply pipe is required to supply steam at a pressure of 2 pounds to 530 square feet of indirect radiation, the equivalent length of pipe being 75 feet.

Solution.—Equivalent in direct radiation $= 530 \times 2 = 1{,}060$ sq. ft. Referring to Table I, it will be noted that a $3\frac{1}{2}$-in. pipe 100 ft. long will supply 1,320 sq. ft. of direct radiation at a 2 lb. pressure, and that a 3-in. pipe 100 ft. long will supply 900 sq. ft. of direct radiation. If the supply main were longer than 100 ft., it would be necessary to use a $3\frac{1}{2}$-in. pipe. But, as the length of the main is only 75 ft. it is safe to use a 3-in. pipe. Ans.

22. Sizes of Mains for Direct-Indirect Radiation. The sizes of mains for supplying direct-indirect, or semi-direct radiators with steam can be found in the manner described for indirect mains, excepting that the equivalent in direct radiation is found by adding 50 per cent. to the amount of direct-indirect radiation.

23. Sizes of Main for One-Pipe Systems.—The pipe sizes given in Table III, which is based on good practice, are such as will insure satisfactory results with single-pipe

TABLE III

SIZES OF MAINS, DIRECT RADIATION, ONE-PIPE SYSTEM

Radiating Surface Square Feet	Length of Main, in Feet								
	20	40	80	100	200	300	400	600	1,000
	Nominal Diameter of Pipe, in Inches								
20	1	1	1¼	1¼	1¼	1¼	1½	1½	1½
40	1¼	1¼	1¼	1¼	1½	1½	2	2	2
60	1¼	1¼	1½	1½	1½	1½	2	2	2½
80	1½	1½	1½	1½	2	2	2	2½	2½
100	1½	1½	1½	1½	2	2	2½	2½	3
200	2	2	2	2	2½	2½	3	3	3½
300	2	2	2	2	2½	2½	3	3	4
400	2	2	2½	2½	2½	3	3	3½	4
500	2½	2½	2½	3	3	3	3½	4	4½
600	2½	2½	2½	3	3	3½	3½	4	4½
800	2½	2½	3	3½	3½	3½	4	4½	5
1,000	3	3	3½	3½	4	4	4	4½	6
1,400	3	3	3½	4	4	4½	4½	5	6
1,800	3½	3½	4	4	4½	4½	5	5	7
2,000	3½	3½	4	4½	4½	5	5	6	7
3,000	4	4	4½	5	5	6	6	7	8
4,000	4½	4½	5	5	6	7	7	8	9
6,000	5	5	5	6	7	7	7	8	10
8,000	5	5	6	6	7	8	8	9	11
10,000	6	6	6	7	7	8	8	9	12
12,000	6	6	6	7	8	8	9	10	12
14,000	7	7	7	8	8	9	10	11	14
16,000	7	7	8	8	9	10	11	12	14
18,000	8	8	8	9	10	10	11	12	14
20,000	9	9	9	10	11	11	12	14	16

systems in which the water level in the return above the boiler water-line (representing the drop in pressure) is from 6 to 12 inches, the steam pressure varying from $\frac{1}{4}$ to $2\frac{1}{2}$ pounds per square inch.

EXAMPLE.—What size of main is required for a one-pipe system to supply 12,000 square feet of direct radiation, the main being 400 feet long?

SOLUTION.—Find 12,000 in the left-hand column of Table III, follow along horizontally toward the right to the 400-foot column, which is the third one from the right, where the proper size required is given, namely, 9-in. pipe. Ans.

Since in single-pipe work the steam and water of condensation flow through the same pipe and frequently in opposite directions, it is necessary to use larger pipes than with two-pipe systems, so as to insure as free a flow of the opposing currents as practicable. Before using Table III, the equivalent length of the main should be found in the manner described in Art. **20.** Bearing in mind that a steam main for steam-heating work should never be less than 1 inch in diameter, and then only for short lengths of mains and for small amounts of radiation, the pipe sizes given in Table III may be multiplied by .8 to obtain the requisite diameter of supply mains for a two-pipe system. The corresponding diameter of return main may then be taken from Table I. In applying Tables I and III to the same case of a two-pipe system, a slight difference in the result may occur; this is due to the fact that the tables represent the successful practice of different engineers rather than absolute values based on purely theoretical considerations.

24. Size of Mains as Affected by Available Drop in Pressure.—The purely physical conditions under which low-pressure gravity steam piping must be installed, such, for instance, as the distance between the boiler water-line and the lowest point in the steam supply main, often determine the size of pipe that must be used for a given job, independently of the calculated steam-carrying capacity of the pipes under ordinary circumstances. The above-mentioned distance determines, in fact represents, practically

speaking, the limit of the drop in pressure for which the piping system must be designed in order to obtain satisfactory results. In operation, the height of the water level in the returns above the water-line of the boiler represents the *available drop in pressure*, which is commonly expressed in inches of water column. It is evident that the distance between the water level in the returns and that in the boiler must always be less than that which represents the extreme limit of pressure drop; viz., the actual distance between the lowest point of the steam supply main and the boiler water-line.

25. The size of steam mains as affected by their height above the boiler water-line is a subject that is worthy of study, for in competition work the pipes must be as small as will safely circulate the steam. Generally speaking, on gravity return jobs the higher the main, the smaller it may be; and the nearer it is to the level of the boiler water-line, the larger must be the main. For instance, Fig. 5 shows how a radiator may be connected up with different sizes of pipe and yet the same heating results be obtained in each case under a 5-pound pressure. In Fig. 5 (*a*), the main has been run so low that it is necessary to use a 2-inch main to prevent such a drop in pressure as would cause the water in the drip *a* to rise into the main and thereby flood the inlet to the pipe *b*. The end of the main is only 3 inches above the boiler water-line, shown dotted, making the use of a large main necessary.

In Fig. 5 (*b*), the available height for the water in *a* to rise is 12 inches; this is due simply to raising the main. A $1\frac{1}{4}$-inch main will then serve the radiator as easily as the 2-inch main in Fig. 5 (*a*).

The main shown in Fig. 5 (*c*) is raised to a height of 36 inches above the boiler water-line, and a 1-inch pipe will now serve the radiators as easily as the radiators in Fig. 5 (*a*) and (*b*) are served by larger pipes. The only difference is that a pressure of about 5 pounds may be carried at (*c*) and about 4 pounds at (*b*), while (*a*) will

work satisfactorily at a pressure of 1 pound, provided, o course, that in each case the boiler water-line does not ris above the dotted line shown. This shows how heatin engineers may run small pipes on some jobs, but must ru large pipes on others. It shows, too, how economy may b exercised in piping a steam job. There are many place

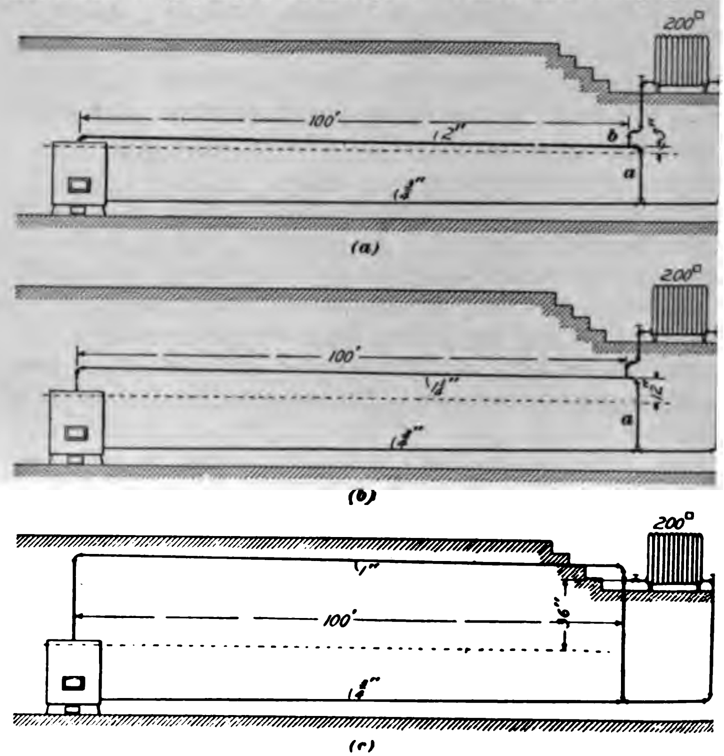


FIG. 5

where the fitter may reduce the sizes of pipes by raisin them, but he must use good judgment, otherwise there wi be times when the water will back up in the mains and caus considerable trouble. The pipe sizes given in Fig. 5 ar the smallest that should be used; to allow a margin of safet it is advisable to make all the pipes one size larger tha shown.

In deciding on the use of small piping in such a case as that illustrated by Fig. 5 (*c*), where the amount of radiation is considerably greater than is supplied in ordinary practice by a 1-inch pipe, it should be borne in mind that satisfactory results will be obtained only when the boiler pressure is sufficiently high to realize the advantage of a greater available drop in pressure, due to the greater distance between the boiler water-line and the lowest point of the supply main. In other words, the plant must be operated continuously at such a pressure as to supply the radiation with as much steam as it will condense, without causing a drop in pressure greater than $\frac{36}{27}$, or 1.33 pounds, a water column 27 inches high exerting a pressure of 1 pound per square inch. If the drop in pressure is to be 1.33 pounds, it is evident that the pressure carried must be several pounds in excess of the proposed drop.

26. The factors given in Table IV may be used in calculating the size of piping for various pressure drops in mains 100 feet long. They represent values obtained by Prof. R. C. Carpenter and are applicable to ordinary house-heating installations, where the amount of radiation does not exceed 2,000 square feet.

TABLE IV

FACTORS FOR BASING SIZES OF MAINS ON AVAILABLE DROPS

Available Drop in Pressure Inches of Water	Multiply Each 100 Square Feet Radiating Surface for Area of Steam Main by		Required Steam Pressure Pounds
	One-Pipe System	Two-Pipe System	
2.0	1.35	.900	1 to 2
6.0	1.01	.675	2 to 3
8.0	.67	.450	3 to 4
12.6	.56	.375	4 to 5
18.0	.45	.300	5 to 6

EXAMPLE.—(*a*) What size of steam supply main for a two-pipe system should be used to supply 1,300 square feet of radiation when the limit of drop is 18 inches and the pipe is to be designed for an available drop of 8 inches? (*b*) Under what boiler pressure should the system be operated?

SOLUTION.—(*a*) In the second column of Table IV, under the heading Two-Pipe System, the factor of .45 is found as corresponding to an available drop of 8 in. According to the directions given at the top of the second column,

$$\text{size of main} = \frac{1,300}{100} \times .45 = 5.85 \text{ sq. in.}$$

The nearest larger standard size of pipe, which is 3 in., would be used. Ans.

(*b*) In the last column of Table IV, a steam pressure of from 3 to 4 lb. per sq. in. is found to correspond to an available drop of 8 in. Ans.

27. Sizes of Returns.—The sizes of return pipes not only depend on the capacity of the system as a whole, but are materially affected by the character of the returns, that is, whether wet or dry. The smallest return piping may be used when the returns are sealed by being carried below the boiler water-line or by being trapped to establish an artificial water-line in them. With wet or sealed returns, it is considered good practice to make the area of the return piping equal to about one-fourth that of the steam piping in plants where the steam pipe is larger than 3 inches in diameter, although some engineers make the diameter of the return in such plants about one-half that of the steam main. Where the steam pipe is less than 3 inches in diameter it is customary to make the return one or two sizes smaller than the corresponding steam pipe. With dry returns, it is considered good practice to make the area of the piping equal to about one-half that of the corresponding steam pipe. It is good practice never to use a return smaller than 1 inch in diameter, although a $\frac{3}{4}$-inch pipe may be employed in some cases where the amount of radiation to be drained is small. Table I indicates sizes of return pipes, with corresponding steam mains, that have been found to work satisfactorily in practice. The diameter of return pipes from indirect heating surfaces should be

ıt 50 per cent. greater than for a similar amount of ct radiation.

8. **Sizes of Drip Pipes for Steam Mains.**—Since quantity of water of condensation to be handled by drip relief pipes is practically an unknown quantity, no eral rule can be given for proportioning them. It has ı found in practice, however, that ordinarily the sizes

TABLE V

IZES OF DRIP PIPES FOR COVERED STEAM MAINS

meter of n Main ches	Length of Steam Main, in Feet					
	100	200	400	600	800	1,000
	Diameter of Drip Pipe, in Inches					
to 2	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$
3	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{4}$
4	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$
5	$\frac{3}{4}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$
6	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	2
7	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	2
8	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$
9	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	$2\frac{1}{2}$
10	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
11	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
12	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$2\frac{1}{2}$	3	$3\frac{1}{2}$
14	$1\frac{1}{2}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4
16	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4

ı in Table V are ample for draining covered mains of ıus lengths. Larger drip pipes than are actually neces- to relieve the steam main of condensation should not sed. Drip pipes should be connected to the return in a manner as not to impede the circulation but rather ıce the velocity with which the water of condensation ıs to the boiler.

29. Sizes of Drip Pipes for Risers.—The sizes of drip pipes at the foot of risers of one-pipe systems depend on the amount of radiation supplied from the risers. Ordinarily, the sizes given for return pipes in the second column from the left in Table I are suitable and will give satisfactory results by using them in conjunction with the figures given in the radiation column under the 5-pound pressure.

EXAMPLE.—A one-pipe riser supplies 700 square feet of direct radiation. What should be the size of the drip pipe that connects its base to the return main?

SOLUTION.—In the right-hand column of Table I, the number nearest 700 sq. ft., and higher than it, is 880 sq. ft. Following along horizontally to the second column from the left hand, it will be noticed that the size of drip pipe required is 2 in. Ans.

30. Dividing Circuits to Obtain Small Mains. Economy of installation is an important feature to be considered in all competitive work. The engineer that can reduce the cost of a heating system below his competitor's figures and still have the system operate satisfactorily, will, in most cases, secure the contract for the work. One way by which considerable money can often be saved on a job is by using a number of separate mains instead of one continuous main. In this way the pipe sizes will be considerably smaller, while the aggregate length will not be materially increased. For instance, Fig. 6 (*a*) shows a continuous single-pipe system main *a* with branches taken off to supply a number of risers. The amount of radiation, in square feet, supplied by each riser is marked on the drawing. The main starts from the top of the boiler with 5-inch pipe and runs all around the cellar, as shown, the lower end terminating in $2\frac{1}{2}$-inch pipe where it connects to the return headers of the boiler. This is an expensive main because it is necessary to use large pipes, not only to compensate for the long distance the steam has to travel but also because the steam condensed in the system must all pass through this main. Owing to the fact that the main must have a pitch down to the return end, the riser connection taken to the last riser supplied by the main is necessarily quite low and generally too near the

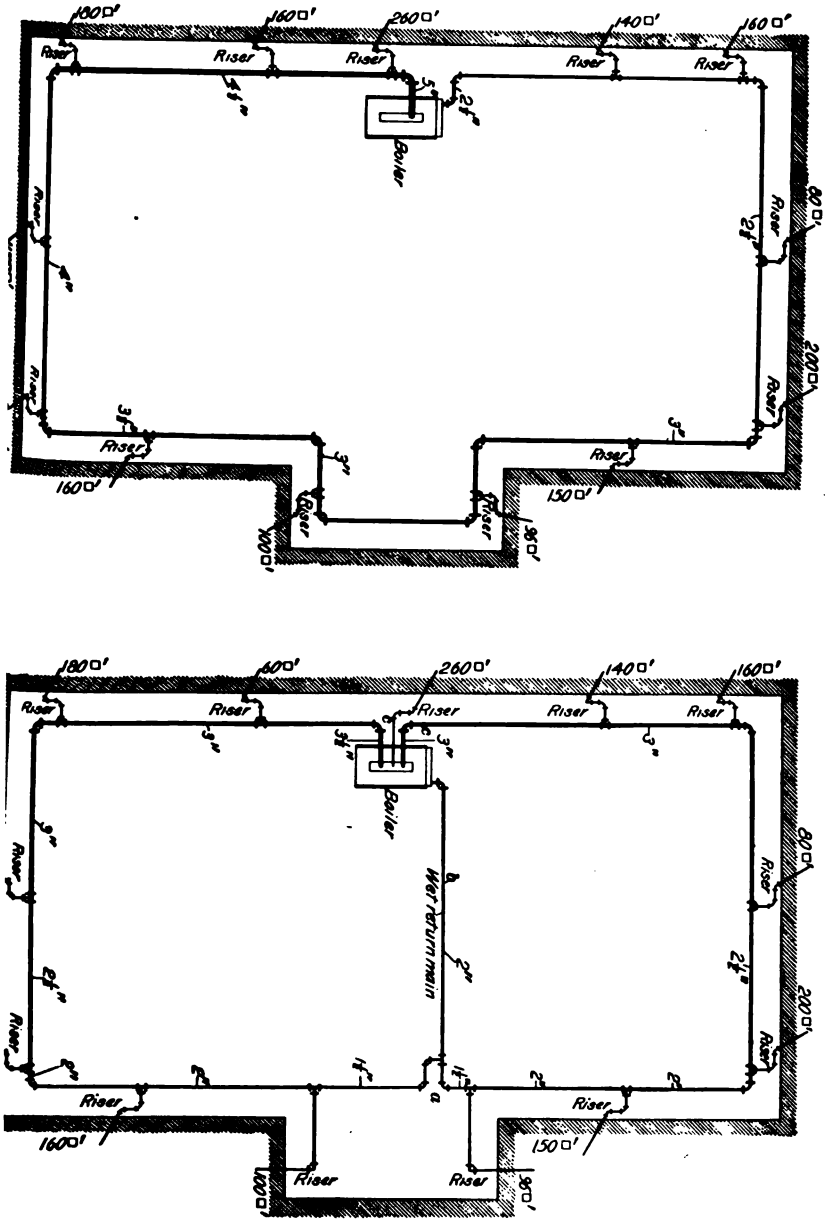

180□'
160□'
260□'
140□'
160□'
Riser
Boiler
80□'
200□'
150□'
160□'
100□'
36□'
Wet return main
Riser
Boiler
180□'
60□'
260□'
140□'
160□'
80□'
200□'
150□'
160□'
100□'
36□'

FIG. 6

level of the boiler water-line. This necessitates a large main so that the drop in pressure will not be so great that the main will become flooded at the lower end. Such a main as is shown in Fig. 6 (*a*) should be used only when it is impossible to divide the main into two or more separate circuits.

In Fig. 6 (*b*) is shown the same building, the same risers, and the same boiler, but the main is divided into two separate circuits, the return ends of which drop to the floor at *a* and join a wet return main *b* that connects to the return headers of the boiler. In order to reduce as much as possible the amount of radiation supplied by each part of the divided main, the riser *c* is connected directly to the top of the boiler, the condensation running back into the steam drum; this relieves the main considerably. The mains shown in Fig. 6 (*b*) have the advantage of being short, and their extreme ends are not as low as the extreme end of the continuous main. The cost of the main shown in Fig. 6 (*a*) will be found to be about 50 per cent. greater than that of the main shown in Fig. 6 (*b*).

31. Pipe Sizes for Complete Systems.—The method generally followed in proportioning pipe sizes for an entire system is indicated by Fig. 7, which shows a boiler *a* connected up complete to a number of radiators by a series of one-pipe risers. The steam main at the right of the boiler has a corresponding return main below it, and the bases of the risers are drained into the return. The steam main should, therefore, be proportioned according to values obtained from Table I, which gives sizes for two-pipe work. The main at the left, however, should be proportioned according to values obtained from Table III, as the main receives the condensation from the risers and thus operates on a one-pipe system. In proportioning steam mains according to these tables, all pipes that supply steam and also convey the water of condensation from the radiators should be considered as belonging to the one-pipe system, and all pipes that are drained so that the water of condensation from each

radiator does not flow through them should be considered as belonging to the two-pipe system.

In marking the correct sizes of the different parts of the heating system on plans or sketches, the sizes of the risers should be marked first, commencing at the top and working down, when the risers are fed from the bottom. Then the sizes of the main should be marked down, commencing at the end farthest from the boiler and working toward the boiler. Thus, the process of determining the sizes of pipes in that part of the system shown at the right of the boiler in Fig. 7 would commence at the top of the riser No. *1*. As

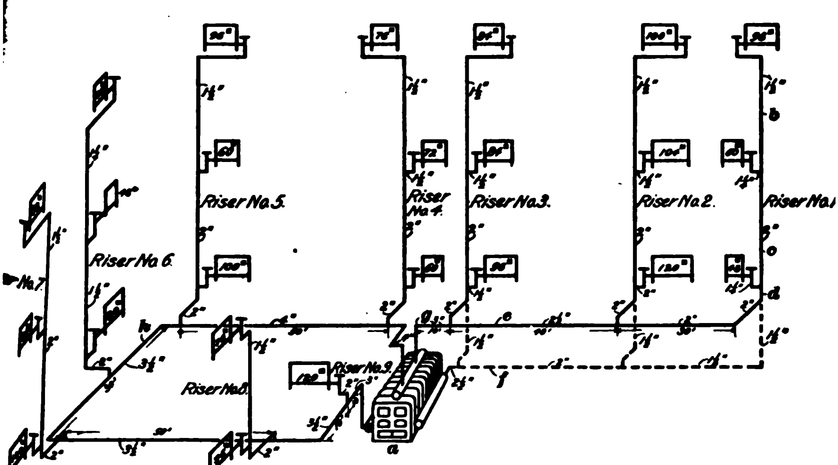


Fig. 7

this riser operates on the one-pipe system, the size of *b*, from Table III, is $1\frac{1}{2}$ inches. The pipe *c* supplies $96 + 60 = 156$ square feet of direct radiation. Referring to Table III, the size of *c* should be 2 inches. The short connection *d* and the pipe between riser No. *1* and No. *2* supplies $156 + 48 = 204$ square feet. Therefore, according to Table III, the size of this pipe should be 2 inches. In like manner, the sizes of the pipes that make up riser No. *2* are found, and marked on the sketch, as shown.

The total radiation supplied by riser No. *1*, which is 204 square feet, plus the total radiation supplied by riser

No. *2*, which is 324 square feet, is the amount that is to be supplied by the main *e*; viz., 528 square feet. Referring to Table I, it will be noticed that a 2½-inch main is required, and the corresponding return main *f* should be 2 inches.

The main at *g* supplies risers Nos. *1*, *2*, and *3*, and the total amount of radiation to be supplied by this pipe is therefore 792 square feet. Referring to Table I, it will be seen that a 2½-inch pipe is too small for this amount of radiation with a 2-pound steam pressure, but it would be correct for a 5-pound pressure. However, as this job is supposed to be operated on a 2-pound pressure, a 3-inch pipe should be used at *g* and a 2½-inch pipe for the corresponding return.

All drip pipes taken from the base of the risers should be proportioned according to the values obtained from the second column to the right of Table I, and are found to be as shown on the sketch.

Risers Nos. *4*, *5*, *6*, *7*, *8*, and *9* are proportioned in the manner previously described for risers Nos. *1*, *2*, and *3*, and their sizes marked on the sketch. The main is proportioned by first determining the size with which it should leave the boiler, then determining the size of the extreme end, making the latter equal to the size of the return main corresponding to the size of the main at the boiler end. The total amount of radiation to be supplied by the main at the left of the boiler is 1,200 square feet. The length of the main is about 150 feet. Referring to Table III, it will be seen that a 4-inch main is required at the boiler. The return main corresponding to this (see Table I, second column to the right) is 3 inches, and hence the tail-end of the main should be 3 inches in diameter. It is now necessary to make a judicious reduction from 4-inch to 3-inch pipe throughout the run of the main, the reduction being as shown in drawing. The 4-inch pipe should be continued around to the corner at *h*, and the 3½-inch pipe should continue from this point to the connection taken off for the 120-square-foot radiator, No. *9*, beyond which it is 3 inches in diameter. Other systems are proportioned in a similar manner by the use of Tables I and III.

EXAMPLES FOR PRACTICE

1. What size of main will supply 250 square feet of direct radiation in an ordinary dwelling house? Ans. $1\frac{1}{4}$ in.

2. What size of supply main 200 feet in actual length, and having two globe valves and two elbows in it, will be required to supply 4,000 square feet of direct radiation at 2 pounds steam pressure? A two-pipe heating system is to be used. Ans. 7 in.

3. What amount of direct radiation will condense as much steam as 274 square feet of indirect radiation? Ans. 548 sq. ft.

4. What is the equivalent in direct radiation of 947 square feet of direct-indirect radiation? Ans. 1,420.5 sq. ft.

5. What size of main in a one-pipe system should be used for 900 square feet of direct radiation and an available drop of 2 inches? Ans. 4 in.

GENERAL HINTS ON PIPING SYSTEMS

HINTS ON ERECTION AND TESTING

32. Erection.—New buildings are piped, while the work of construction proceeds, as soon as the walls are up and the roof is on. On large jobs, the risers are usually put up first; next the horizontal branches are constructed, proceeding always from the riser toward the radiators, and lastly the mains are put in place. The returns are erected at the same time and in a similar manner. In many cases, however, particularly in small buildings, the mains are run in first, then the risers, and finally the radiator connections. This latter method avoids the use of right-and-left fittings, or unions, between the risers and the mains.

All radiator connections should be promptly capped, that is, closed with a cap, as soon as erected, and all openings in T's and other fittings should be plugged at once, so that no dirt may get into the pipes.

During the erection of a steam-heating plant, the matter of expansion must be considered carefully. The best point for fastening each main pipe so that its expansion will cause the least disturbance should be determined by close examination. Care must be taken to have every such pipe *free* at

the boiler, the valve should be of the gate pattern. When a valve is placed in the steam main, it should be close to the boiler. When two or more boilers are connected to one main, each valve should be placed in such a manner that it closes against the flow of steam from the other boiler, and the connecting union at the boiler should be between the boiler and the valve. Valves in the connections to radiators, coils, or stacks, should be so placed that the disconnecting union is between the valve and the radiator. Angle valves are similar to globe valves in the operation of closing, but they do not offer as much resistance to the flow of steam as do globe valves, in place of which they may in some cases be used to better advantage. Angle valves are generally used on radiator connections, especially where the piping rises through the floor to supply a single radiator. Horizontal branches to radiators should be provided with gate valves, so that the flow will be direct, and in order that there may be no chance of accumulation of water of condensation in the branch. Some situations require the use of valves that combine the features of the angle and globe types.

35. In erecting apparatus for residences, the smaller the number of valves to be operated the less trouble there will be in getting the servants having the apparatus in charge to understand the working of the system. In private houses, valves should not be placed in the boiler connections; i. e., in the main steam or main return pipes or risers. No valves should be used except a check-valve on the main return, and it is necessary to make sure that this is in working order before the apparatus is put in operation. Servants are poor mechanics, and if there are no valves in the mains to be closed, serious damage cannot be done. Large heating systems require careful men to handle them, and hence the risers and mains may advantageously be supplied with valves for dividing the piping system into sections.

OPERATING A HEATING PLANT

36. A steam-heating plant requires but little attention. All the engineer, janitor, or other operator has to do with an ordinary system while it is in operation is to insure a steam pressure sufficient to produce good heating results. In ordinary cases, this pressure is from 1 to 5 pounds by the gauge. He should inspect the system occasionally, at least once a month. In such an inspection he will invariably find that some radiator valves leak through the stuffingbox. These can easily be repacked without affecting the operation of the heating system, for by closing the radiator valve the steam pressure is taken off the stuffingbox. He may find that some air vents spit water or blow steam when they really should be closed, because the radiators on which they are screwed are hot to the extreme end loop. These defective air vents should immediately be repaired or adjusted, as each case may require. If the inner parts are broken or irreparably defective, the engineer should replace the old vent with a new one; they are too cheap to waste much time on in repairs. The engineer should keep a stock of air vents on hand. If when steam is on and the radiator valve open, the radiator does not heat, it is evident that the air valve is so choked or otherwise closed that it will not let out the air.

When a radiator valve is closed and a hissing or hammering noise is heard in the radiator, it is evident that the valve is not tight. A new disk, preferably of the Jenkins type, should be put on. This requires shutting off steam from the riser to which such a radiator is connected. If the radiator is connected on the two-pipe system, the return riser must also be shut off, otherwise the steam pressure may back up the water of condensation into the radiator through the returns and flood the building; or steam in the return riser will blow through the radiator and escape at the radiator valve when the bonnet is unscrewed.

Before replacing a valve stem and disk, it is proper to examine the valve seat carefully to see if it has a smooth,

true face. If a groove has been ground out or the valve face is rough, it is advisable to grind it or to face it smooth and true with a reseating tool.

Before the steam is turned on a heating system in the autumn, all necessary repairs should be made and everything should be clean and ready for firing up at a moment's notice. The heating boilers should have been blown out and cleaned the preceding spring, when the system was put out of service for the summer. The return mains should all be drained clear at the same time. All valves should be examined and repaired, if necessary, during the summer. This will prevent considerable trouble during the winter.

As floors and walls are liable to settle, it is often necessary to readjust the steam-pipe hangers so that the grades of the pipes may be adjusted to prevent water hammer. This, also, should be attended to during the summer. Indeed, nearly all the repairs that a heating system of the ordinary character requires can be made during the summer when the engineer in charge of it usually has some spare time. If a heating system receives proper attention during the summer, it should run all winter without repairs.

Occasionally a radiator will gradually fill up with water. This occurs in a one-pipe system when the steam valve remains nearly closed for a considerable time, but not shut tight. The steam is then condensed as rapidly as it enters, and the opening is so restricted that little water will escape. The same thing will happen in a two-pipe system if either valve is closed while the other remains open. By opening both valves wide, the water will almost noiselessly pass out into the return, but in the one-pipe system, as soon as the valve is opened, a violent struggle will begin between the entering steam and the escaping water. The result will be a succession of rumbling, hammering, and snapping noises, which will continue for several minutes. If the supply pipe is long the noise is likely to be prolonged to an annoying extent.

In a large heating system, the amount of water to be returned to the boiler is so great that it becomes very

difficult to pass it through the steam-supply pipes without interfering seriously with the flow of steam to the radiators. The difficulty reaches a maximum in the coldest weather, the greatest amount of condensation occurring at the same time that the largest supply of steam is required. A single-pipe system must be carefully planned to avoid failure at this critical time, and it is good policy to attach returns at some of the principal points to intercept the water and prevent its flooding the riser connections. The two-pipe system, however, when carried out completely, has a certainty of operation and freedom from noise that in many cases makes it much superior to the one-pipe system.

STEAM-HEATING PIPE SYSTEMS

(PART 2)

METHODS OF INSTALLATION

DIRECT HEATING SYSTEMS

INTRODUCTION

1. The low-pressure, gravity, circulating apparatus commonly used for warming buildings by steam is essentially composed of: (1) a boiler, or steam heater, as it is often called, in which steam is generated by the heat of combustion of some fuel; (2) a number of radiators or coils, so constructed that steam from the boiler may flow into them and be condensed by transmitting heat through the coils or radiators to the air and objects surrounding them; (3) a system of pipes that convey steam from the boiler to the radiators, and return the water of condensation to the boiler when the steam has parted with its latent heat; that is, when it has been condensed.

2. Broadly speaking, there are two general systems of piping buildings, the *one-pipe system* and the *two-pipe system*, both of which are frequently modified to suit peculiar local or other conditions. The chief difference between the several systems consists, in a large measure, in the method of arranging the piping for returning the water of condensation to the boiler. Various methods of arranging the piping are employed, and many modifications of the different systems are used in practice. Those most frequently used are described and illustrated farther on.

The comparative economy of the two systems depends largely on the conditions under which they are installed. When properly designed, it has been found in practice that both systems give equally satisfactory results. However, considerable expense, both in material and labor, is often saved by the fitter in using the one-pipe system, or a combination of the latter with some of the features of the two-pipe system. The intelligence with which modifications of either system are planned has much to do with the efficient operation of the apparatus. The expense of installation has been found to be greatly affected by local practice; that system with which the workmen in a given section of the country are most familiar is generally the cheapest to install. Throughout the western portion of the United States the one-pipe system is regarded with particular favor, and it is there successfully used in some of the largest office buildings and other large structures. Somewhat greater care is necessary in laying out one-pipe systems, in order to make satisfactory provision for the flow of steam and the water of condensation in the same piping. The fact that the currents of steam and water move in opposite directions necessitates larger piping, properly proportioned, and carefully graded.

ONE-PIPE SYSTEMS

3. General Description.—A very common method of distributing steam to the several radiators in a building is by means of the **one-pipe system,** shown in Fig. 1. The boiler *a*, which is set on the cellar or basement floor, furnishes steam at a very low pressure, usually from 2 to 5 pounds by the gauge. The steam main *b*, the duty of which is to convey steam to the several risers *c*, *c* through which it flows to the radiators *d*, *d*, placed within the rooms to be warmed, is connected to the steam space of the boiler and is so suspended from the floor joists by hangers that it will have a uniform fall of about $\frac{1}{2}$ inch in 10 feet from its highest point, which is immediately above the boiler, to its lowest point *f*. When steam is generated in the boiler, it is forced

into the steam main; from there into the risers; and thence into the radiators. The air that the pipes contain is forced out of the system to the atmosphere through air vents or small valves placed at suitable points in the system, usually on each radiator at the end opposite the steam inlet. The air is forced ahead of the steam, and if it finds no outlet it remains in the pipe and excludes the steam. As steam flows

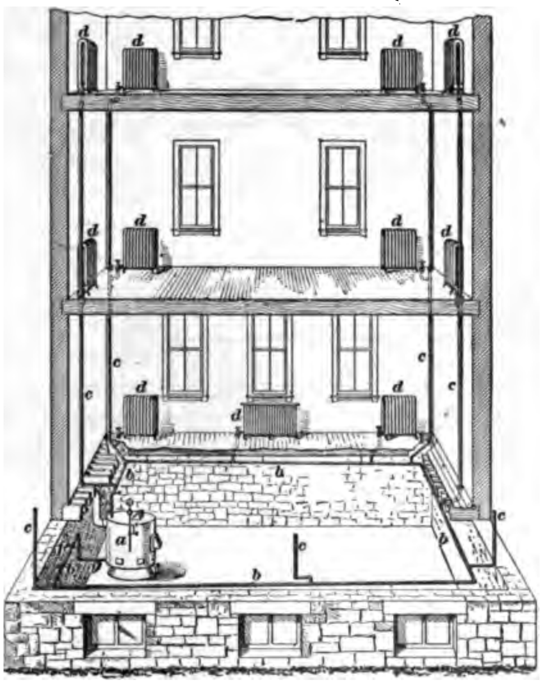


FIG. 1

through the main and the risers, part of it will be condensed by transmission of heat through the pipes to the air and objects surrounding them. The water of condensation will fall by gravity to the bottom of the steam main, flow to its lower end *f*, and enter the bottom of the boiler through the return pipe *g*. The water of condensation from the radiators flows out therefrom and down the risers, through the riser connections, and into the steam main, against the flow of

the steam. If the riser connections to the steam main or radiator connections to the riser have too little pitch, or if the pipes are too small, the flow of the water of condensation through them will be resisted to such an extent by the flow of steam that the water of condensation will not flow off as quickly as it is formed, the result of which will simply be that the water will accumulate in the pipe until the latter is entirely closed, and snapping and hammering noises known as water hammer will take place. The steam main should be made sufficiently large to prevent such a difference between the pressure in the boiler and that at the point *f* as would cause the water to back up in the main and retard the flow of steam to any riser connection.

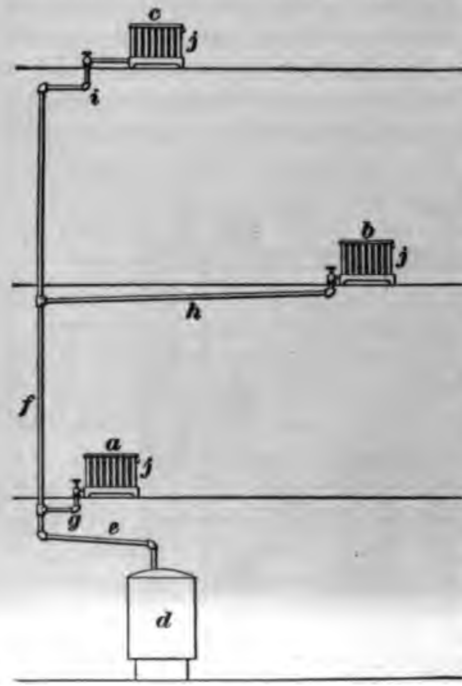


FIG. 2

4. **Separate Main System.**—The simplest form of the one-pipe gravity system of heating by direct radiation is illustrated in Fig. 2, which shows an arrangement of apparatus suitable only for heating small houses, wherein the boiler can be centrally located. The radiators *a*, *b*, *c* are shown at different heights and distances from the boiler *d*, the steam main *e* connecting to the riser *f*, the branches *g*, *h*, and *i* being connected as shown. Valves are placed in the branches

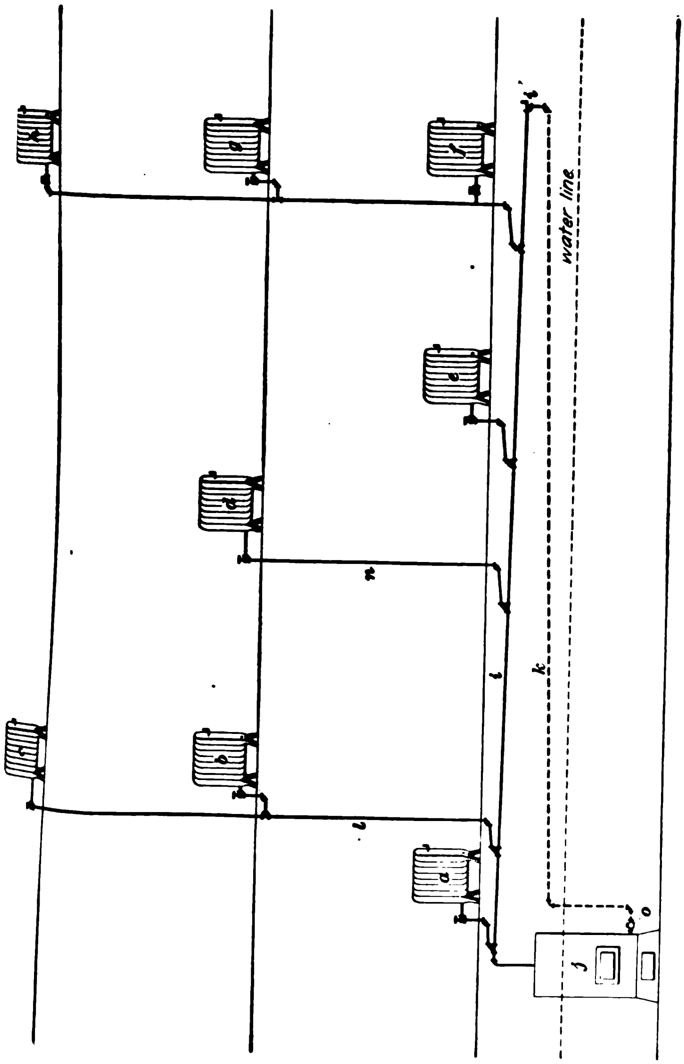


FIG. 3

to the radiators, as indicated, and air valves are located at *j*, *j*. Steam from the boiler *d* passes through the pipe *e* and through the riser and branches to the radiators. The water of condensation from the radiators drains into the branches, thence to the riser and through the pipe *e* to the boiler. It is evident that the pipe *e*, as well as the branches *g*, *h*, and *i*, should be large enough to allow the steam and the water to flow in opposite directions. The branches are run at such a pitch that the water of condensation cannot be impeded in its flow back to the boiler. A very long branch, as at *h*, should not be used in a system of this kind, as sufficient pitch can seldom be given to a long branch; it is better to run a separate vertical pipe to the radiator. The riser *f* must be run as straight as possible; if offsets are made in it, they must have a good pitch so as not to form a pocket in which water can lodge.

5. Circulating Main System.—A single-pipe system with a circulating main is illustrated in Fig. 3. The radiators *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, are connected to the risers and the main in a manner similar to that shown in Fig. 2, but the main *i* is extended to supply all of the rising pipes. If the main *e* of Fig. 2 was long instead of short, the grade of the pipe would require the boiler to be set very low, and the size of the pipe would have to be very large to allow the water and the steam to circulate. The main *i*, Fig. 3, is graded downwards from the boiler *j*, so that the steam and water of condensation flow in the same direction.

The water of condensation flows to the extreme end *i'* of the main, where it will drain into a return pipe *k*, graded in the opposite direction, and carried back to a point near the boiler, where it drops and connects to the boiler below the water-line. The water of condensation from the risers flows against the steam to the main *i*, and therefore the branches to the risers must be of ample area. The branch connections should be taken directly from the top of the main, or at an angle of 45°. The first floor radiators, as at *a* and *e*, are usually connected directly to the main. If the mains are large the first-floor radiator branches can be

e boiler *b* and branches are taken therefrom, one extending ward the right, while another extends toward the left. ach of the branch mains is smaller than the main at the iler. The branch main *c* to the left connects to the er *d*, and is so graded that the water of condensation om radiators connected to the riser *d* drains toward the treme end of *c*. The main *e* to the right extends to the nnection for the riser *f*, and a T just beyond this riser conection allows a drip pipe *h'* to relieve the main of condensaon. The main may then be reduced in size and extended the branch connection to the riser *g*, where another drip pe *h'* is placed to relieve this section of water of condensaon. From this point, the main is extended to supply nother radiator, the main being graded downwards to a oint beyond the radiator-branch connection, where a drip pe *h* is provided, as also at the end of the main at the left. he riser connections are made to the top of the main. The adiator branches at *i* show the T in the riser above the oor, the outlet of the T being turned to the right, and into it is screwed a nipple to which is attached another T with the outlet for the branch pitching up a little from the horizontal. The pipe to the radiator at the right is connected to the run of the last-mentioned T, while the pipe to the radiator on he left is connected to the branch or side outlet of the T, e piping being offset around the riser. The radiator conections at *j* are made under the floor in the space between the latter and the ceiling of the floor below. The radiator connections at *i* should be provided with gate valves. The drip pipes *h*, *h* drain the ends of the mains, while the drip pipes *h'*, *h'* drain the mains at intermediate points. The drip pipes *h'*, *h'* connect to the return main at the top or side, as may be required; they are shown as being carried over to the wall, so as to allow clear space beneath them. The main return pipe *k* is run along the side wall above the boiler water-line, and is therefore a dry return. The two branches of the return pipe are connected together at a point near the boiler, where the pipe drops to a point near the floor and is then carried over and connected to the return opening of

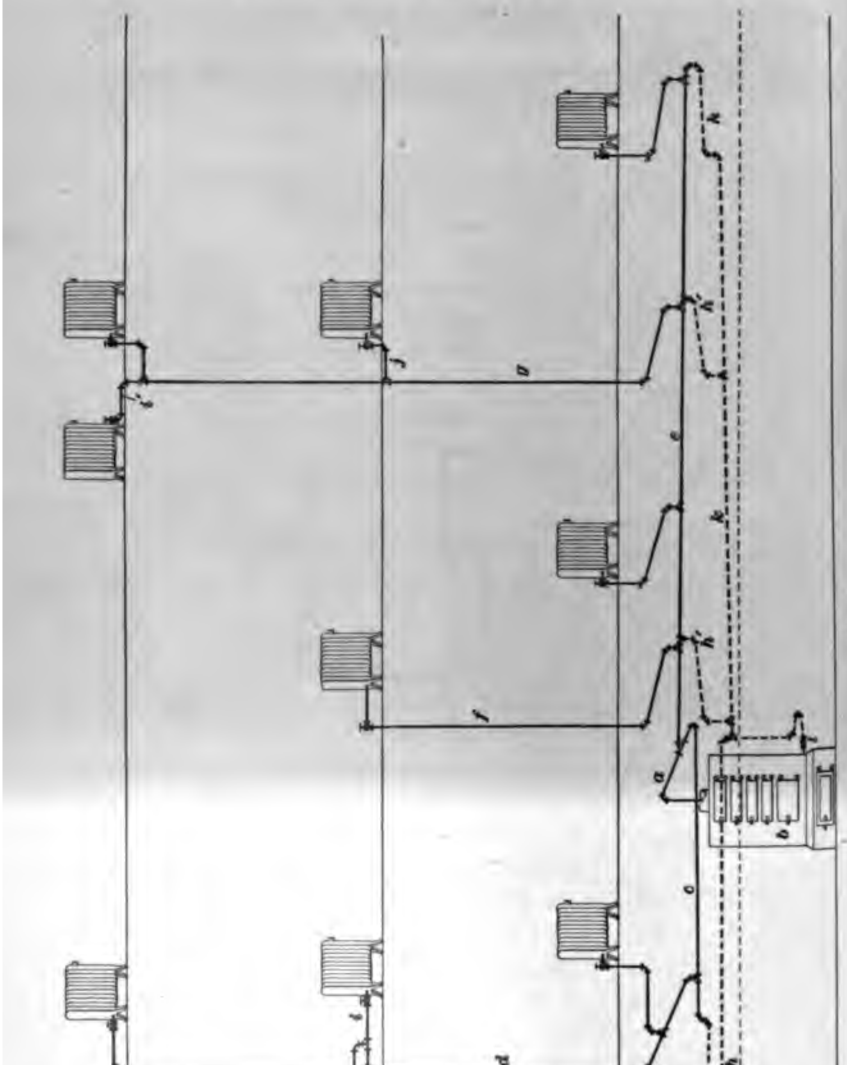


FIG. 5

the boiler b and branches are taken therefrom, one extending toward the right, while another extends toward the left. Each of the branch mains is smaller than the main at the boiler. The branch main c to the left connects to the riser d, and is so graded that the water of condensation from radiators connected to the riser d drains toward the extreme end of c. The main e to the right extends to the connection for the riser f, and a **T** just beyond this riser connection allows a drip pipe h' to relieve the main of condensation. The main may then be reduced in size and extended to the branch connection to the riser g, where another drip pipe h' is placed to relieve this section of water of condensation. From this point, the main is extended to supply another radiator, the main being graded downwards to a point beyond the radiator-branch connection, where a drip pipe h is provided, as also at the end of the main at the left. The riser connections are made to the top of the main. The radiator branches at i show the **T** in the riser above the floor, the outlet of the **T** being turned to the right, and into it is screwed a nipple to which is attached another **T** with the outlet for the branch pitching up a little from the horizontal. The pipe to the radiator at the right is connected to the run of the last-mentioned **T**, while the pipe to the radiator on the left is connected to the branch or side outlet of the **T**, the piping being offset around the riser. The radiator connections at j are made under the floor in the space between the latter and the ceiling of the floor below. The radiator connections at i should be provided with gate valves. The drip pipes h, h drain the ends of the mains, while the drip pipes h', h' drain the mains at intermediate points. The drip pipes h', h' connect to the return main at the top or side, as may be required; they are shown as being carried over to the wall, so as to allow clear space beneath them. The main return pipe k is run along the side wall above the boiler water-line, and is therefore a dry return. The two branches of the return pipe are connected together at a point near the boiler, where the pipe drops to a point near the floor and is then carried over and connected to the return opening of

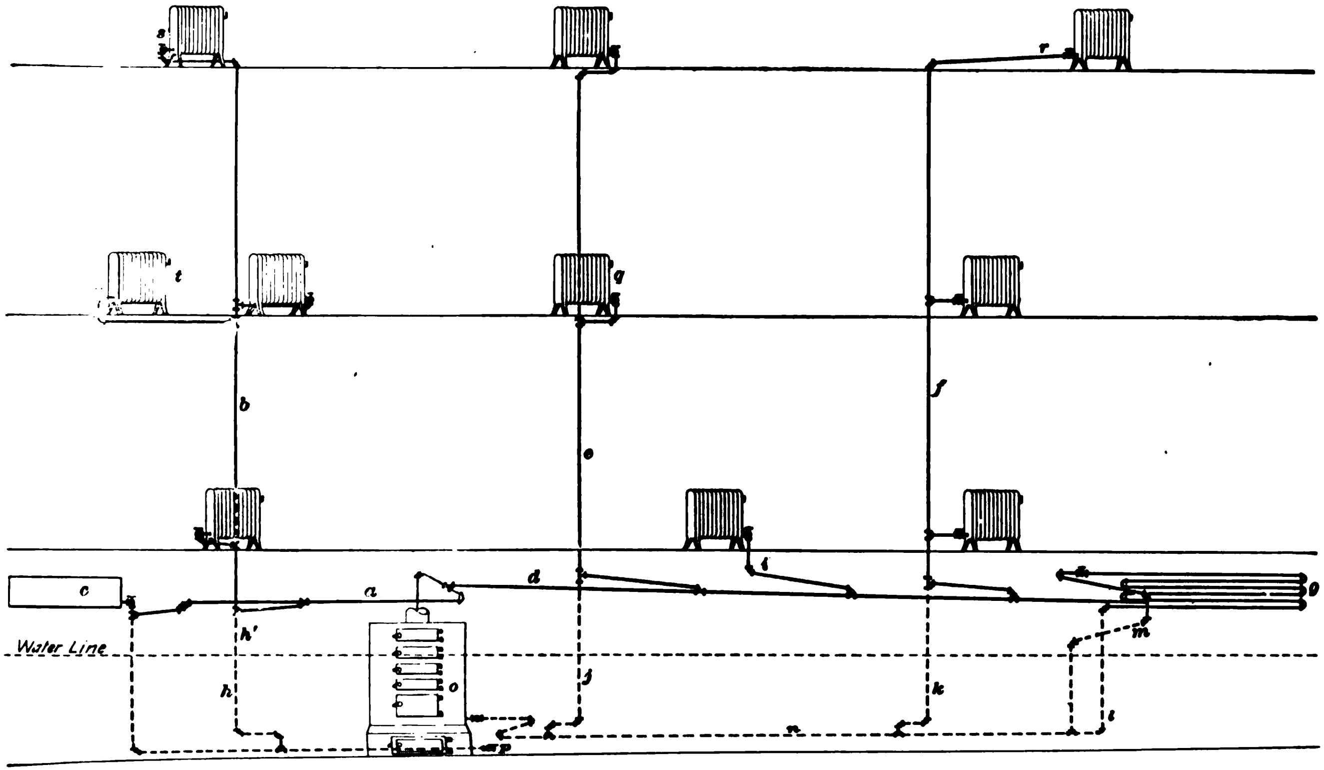


FIG. 6

the boiler. A check-valve is placed in this connection at *l*, so that the water in the boiler cannot be forced back into the return pipe. The method of piping shown in Fig. 5 has the advantage that the supply pipes may be made smaller than those shown in Fig. 3, as the steam and water do not pass in the same pipe for any great distance, the drip pipes taking care of the condensation as it accumulates.

7. **Dripped Riser System.**—The modified form of the single-pipe system shown in Fig. 6 is known as a **dripped riser system.** It is essentially a wet return system. The steam main is shown as following a direction similar to that indicated in Fig. 5. The branch *a* connects to a riser *b*, and an indirect radiator *c* at the side wall above the boiler water-line. The main *d* extends to and connects with the risers *e* and *f* and a coil *g* on the side wall at the extreme right. The branch connection to the riser *b* is taken from the bottom of the main *a*, so that water of condensation from the main and that which comes from the radiators may be drained into the return main by the drip pipe *h* from the drip pocket at the bottom of the riser. From the branch main *d* a riser connection to the riser *e* is taken from a side outlet, and another riser connection *i* just beyond is taken from the top of the main. The branch connection to the riser *e* pitches toward the drip pipe *j*, but if required, it might be pitched toward the main, in which case the drip pipe *j* will drain the condensation of the riser and connected radiators only. The main *d* should not be reduced at the connection to the riser *e* if the branch pitches toward the main, neither should the main be reduced more than one size when such a branch pitches away from the main. The connection to the riser *f* is taken from the top of the main and here the main should not be reduced, as the drip pipe *k* drains the condensation from the riser and connected radiators only. If the main extended a great distance beyond the connection to the riser *f* the pipe would either be continued the same size to the end, or a drip pipe would have to be placed to relieve it of condensation. As shown, however, the main extends

only far enough to supply a coil on the side wall. The **T** for the wall coil and drip connection is put on bull-headed, that is, the main connects to the side opening of the **T**, while the connections to the coil and the drip pipe are made to the run of the **T**. This method of making the connection, although not as sightly as would be a **T** on the run with an elbow for the drip, allows the steam to separate more thoroughly from the water of condensation. Since the branch to the coil connects into the top of the main, and a separate drip *l* from the bottom of the coil is provided, it is apparent that the coil has a two-pipe connection. From the **T** on the main to which the branch connection for the wall coil is made, a drip *m* is taken to drain the main. As the main return pipe is at the side wall, the drip pipe *m* is carried over to the wall and then dropped into the main return. The drip pipe *j* is carried downwards to a point near the return main, to which the final connection is made by using two elbows and two nipples and a right-and-left coupling in the manner indicated. This permits the main return to be run before the final connection of the drip pipe is made, and it also allows for expansion and contraction. If the drip pipe *j* was connected directly into the return main it would have to be put together with a union or a long screw, as there is no spring between the riser connection and the return main. The drip-pipe connection could not otherwise be made unless the return main was forced out of line, or the riser was forced upwards. The right-angle turn in the drip pipe allows the long part of the pipe to be sprung to one side, and the right-and-left coupling and nipples provide an easily made final connection. The return main *n* may be run along the side wall at any height below the water-line of the boiler *o*, or it may be run under the floor. When a return or other pipe is run under the cellar floor, it should be run in a masonwork trench, so that dampness will not cause it to rust, the trench being provided with covers, so that the pipe may be easy of access. When the return main is run below the return opening of the boiler, there should be some means of draining it, and for this

purpose a cock *p* should be placed at the lowest point on the return. Fig. 6 illustrates other methods of running the connections to radiators than shown by preceding diagrams. At *q* the radiator is in front of the riser, and the connection is run beneath the floor; a long radiator connection run above the floor is shown at *r*. The latter connection should be avoided whenever possible; if it must be used, the radiator should have high legs, so that a proper grade can be given to the pipe; and a pipe one size larger than ordinarily required by the radiator must be used. The connection to the radiator at *s* is run underneath and between the legs of the radiator and has an angle radiator valve. Of the radiators at *t*, the one to the right is too close to the riser for a direct connection; consequently, a pipe is carried back of the radiator from the outlet of a **T** in the riser, an offset corner angle valve being used in making final connections. The radiator on the left at *t* is far enough from the riser for a direct connection to be made above the floor.

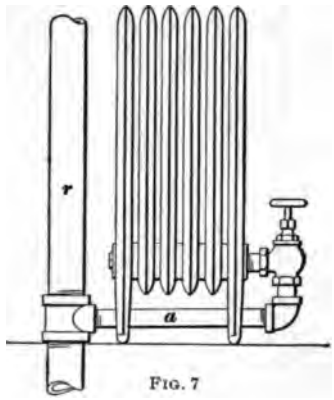


FIG. 7

8. Fig. 7 illustrates, in detail, a common method of connecting a radiator to a riser *r* when it is too close to the riser for a direct connection. The pipe *a* is run between the legs of the radiator and final connection is made by means of an angle valve. This, it will be observed, is virtually the connection employed for the radiator at *s*, Fig. 6.

9. Sealed-Drip System.—The sealed-drip, or false water-line, system is one in which sealed-drip connections are used in combination with a dry-return pipe for the purpose of positively controlling the direction of the circulation by preventing the steam in the dry-return main from by-passing or short-circuiting into the riser. This system also allows the drainage of the riser where the branch is taken

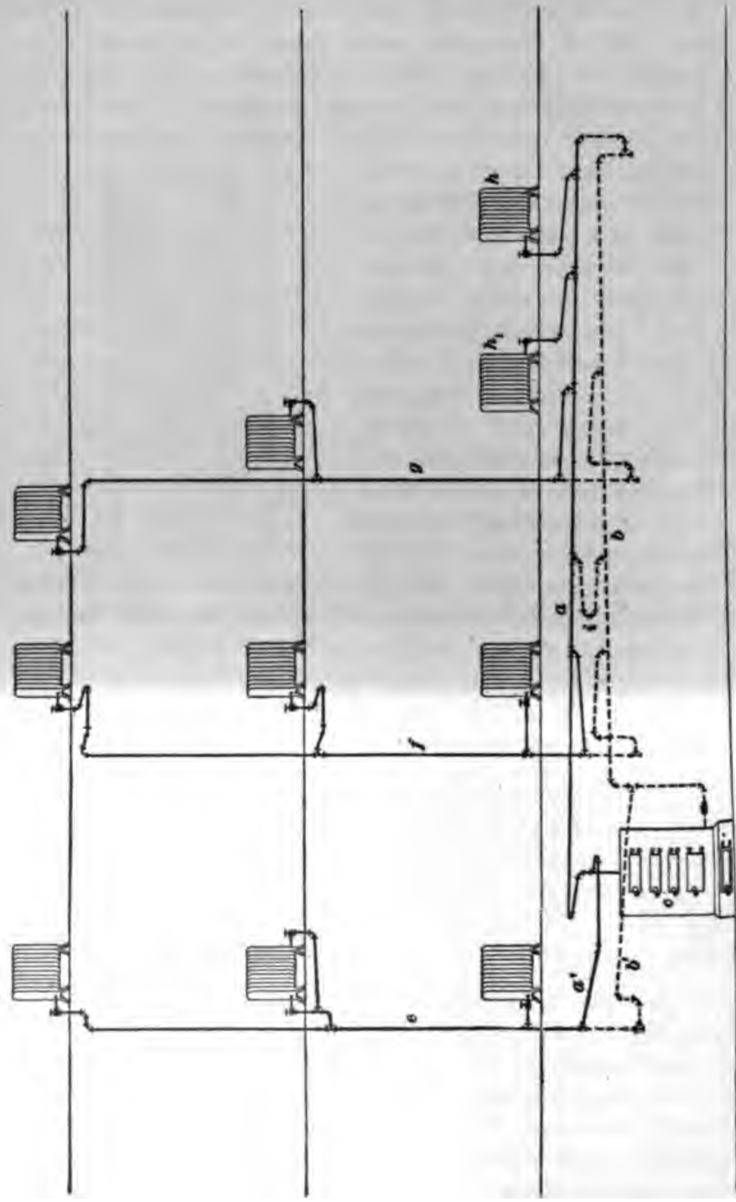


FIG. 8

from the bottom or side of the main and drained toward the riser. Sealed drips are not recommended for use in a general system, except where it is necessary to carry the return main above the water-line of the boiler; as may be the case where there are connections that must be separately drained, and which might cause an unequal pressure between the steam and return mains if the two were not equalized by bleeders or dry drip connections.

A sealed-drip one-pipe system is shown in Fig. 8, where *a* and *a'* are branches of the steam supply main, and *b* and *b'* branches of the dry-return main. The riser *e* drains into the return main branch *b'*; the risers *f* and *g* drain into the return main branch *b*. The radiators h_1, *h* take their steam from and drain directly into the steam-supply main *a*. The drips from

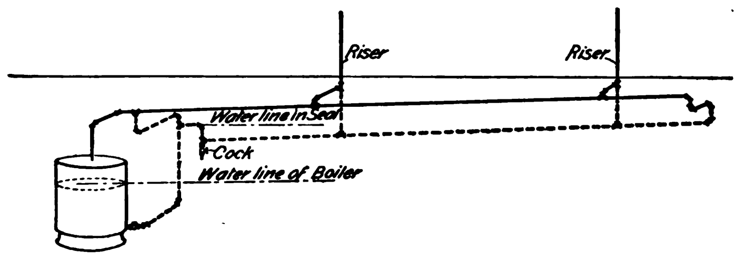


FIG. 9

the foot of the risers *e*, *f*, and *g* are carried below the level of the return mains *b* and *b'* and then up again, entering the return mains as shown. A trap is thus formed at the foot of each riser, which traps collect water and then form water seals that prevent steam in the return main branches from passing directly to the risers. A trap is also formed at the junction of the steam-supply main *a* and return main *b*, the water seal of which prevents steam in the return main from passing directly to the radiators h_1, *h*. Reflection will show that the water seals of the traps compel the steam to pass directly from the steam main to the risers; in other words, the traps compel a positive steam circulation. In order that the steam pressure in the risers may not force the water seals of the traps into the return main, as is likely to

occur through a reduction in the steam pressure in the return main, this main is connected with the steam-supply main by the so-called *balance pipe i*, which insures the same pressure in both mains at all times.

10. By means of a water seal an artificial water-line may be established in a return pipe above the water-line of the boiler, the drips connected to the return main being sealed in the manner shown in Fig. 9, which, practically speaking, represents a combination of the systems illustrated by Figs. 6 and 8.

11. Unusual Connections.—To obtain satisfactory results in meeting the requirements imposed by the peculiar conditions under which one-pipe systems are sometimes installed, especially in old buildings previously heated by other means, the steam fitter must exercise considerable ingenuity in making such unusual connections as are often found to be necessary. Fig. 10 shows a number of different connections that may be made to the radiators on a one-pipe system, but it does not represent the usual method of arranging such a system. The coil *a* is connected to the riser by a single pipe, for which style of connection the air vent should be placed at the end of the top pipe. The coil *b* is connected to the same riser by two pipes; the steam connection is taken from the riser at a level with the top of the coil, or above the coil if desired. The return connection is made by placing a **T** at the end of the coil, the air pipe being taken from the top of the **T**. The return pipe is taken from the bottom of the **T**, dropping downwards and connecting into the riser below the level of the coil. A check-valve should be placed in this connection below the coil. As shown in detail in Fig. 11, the coil *c*, Fig. 10, is served by a single connection taken from the branch outlet of a **T** in the riser and connecting to the top pipe of the coil. The return connection is made in practically the same way as on coil *b*, except that it connects to the run of the supply connection, with a check-valve in the return pipe, as shown. The radiator *d* is connected to the riser by steam and return

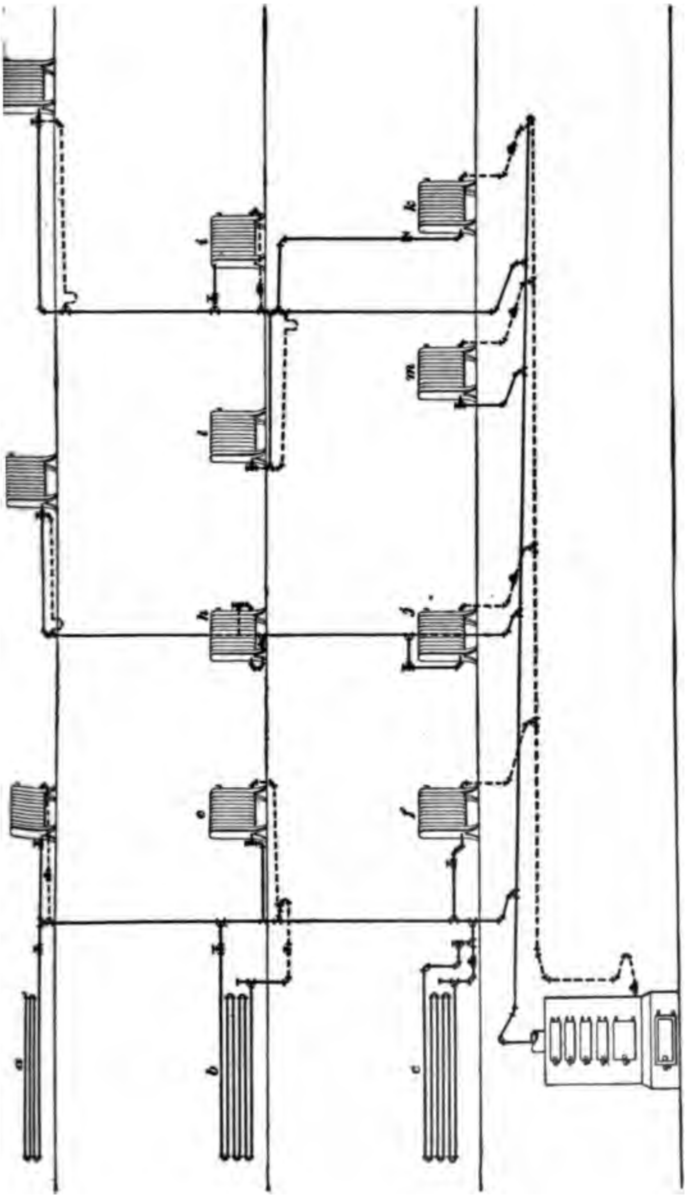


FIG. 10

branches, the steam pipe rising above the inlet to the radiator, and pitching toward the radiator to which it is connected by a gate valve. The return connection passes back of the radiator from the opposite end and pitches down to the riser, to which it is connected below the steam connection. A check-valve is placed in the return to prevent the steam backing through it into the radiator and thereby closing the air valve before the steam has circulated through the whole radiator. The radiator *e* has the steam connection run over the floor and graded toward the riser, the return connecting into the riser beneath the floor. The radiator *f*

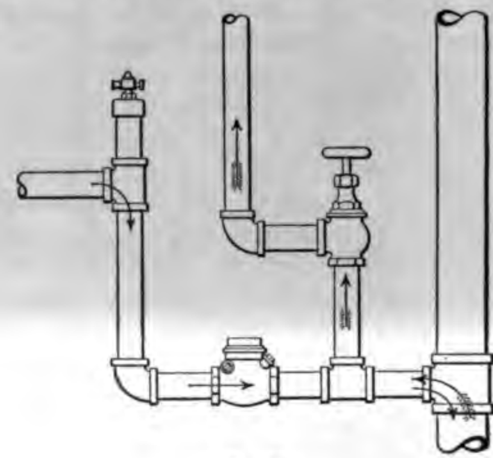


FIG. 11

has the steam-supply pipe connected to the riser and the return connected directly into the dry-return main in the cellar. The radiator *g* is connected by a special valve having separate ports for the steam and return connections, although the valve has but one connection to the radiator. The connections to radiators *h* and *i* are modifications of those for *d*. Those to *j* and *k*, are modifications of those for *f*. The branch to the radiator *l* is dripped just below the point where the valve connects to the radiator. The steam and return connections of the radiator *m* are made directly with the mains in the cellar, a check-valve being

used in the branch return. The connection to radiator *n* is the same as that to *g*, with the return pipe under the floor. With the one-pipe system, when a radiator is located at a considerable distance from the riser, as the radiators *g*, *l*, and *n*, so that proper drainage becomes difficult, it is advisable to arrange the connections in the manner indicated in Fig. 12. The supply pipe *a* and the return or drip pipe *d* are both connected to the riser *r*, a siphon, or water-seal, trap being placed at *b* to prevent a reversal of the direction of the steam circulation in the radiator. All the water of condensation in the pipe *a* passes into the drain pipe *d* without entering the radiator. In all cases the radiators should have air valves at the end opposite to that at which the steam connection is made.

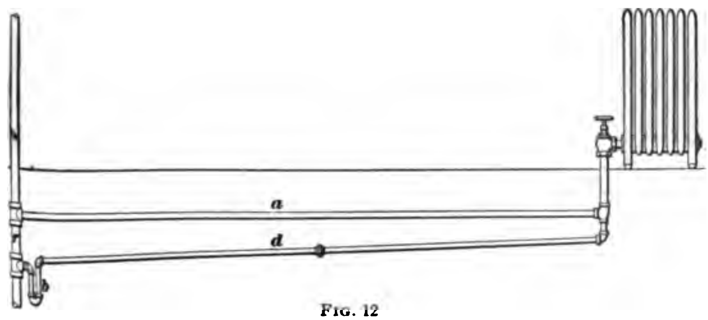


FIG. 12

12. One-pipe connections to radiators and coils are not always desirable, as, for example, when the valves used on the radiators are not steam-tight when closed, the steam being forced into the radiators through the small aperture due to imperfect closure. The steam thus admitted is condensed and accumulates in the base of the radiator. Then, when the radiator valve is opened, the steam passing through the water will cause water hammer. When the water and steam are of practically the same temperature, the water will ordinarily flow noiselessly back to the boiler. Trouble from water hammer will also be met with in two-pipe systems, but as the radiators are connected by two pipes instead of one, the water has a freer passage. Ordinarily, but

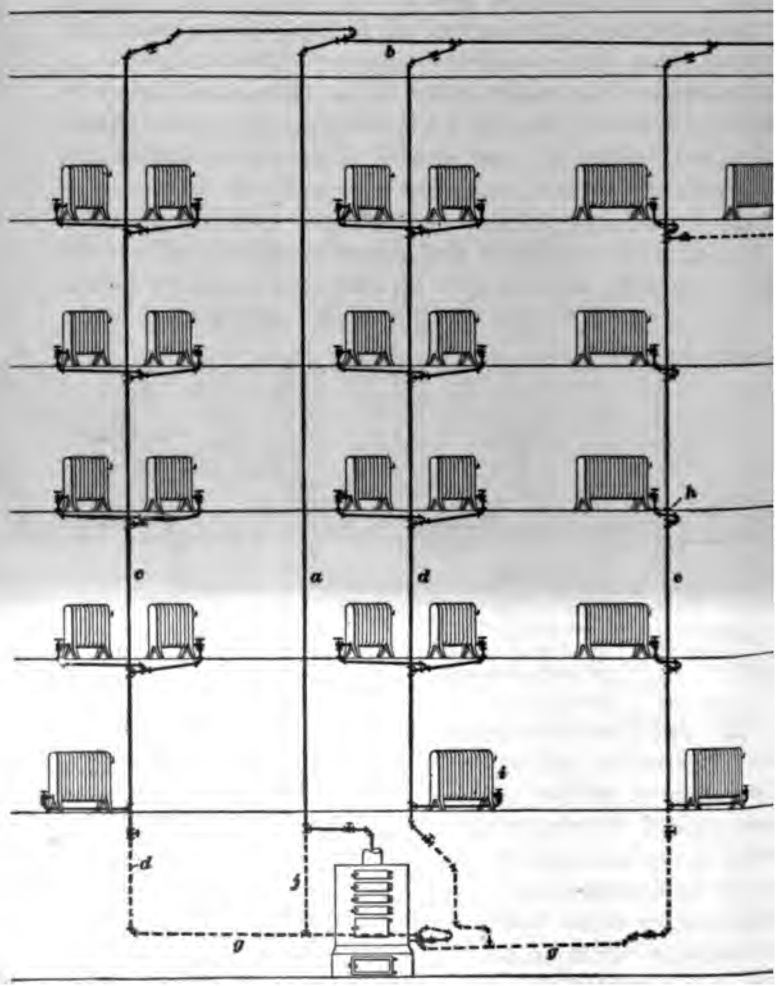


FIG. 13

little trouble from water hammer is experienced when a check-valve is placed on the return connection, as indicated in connection with radiators *b*, *d*, *h*, *i*, etc. in Fig. 10.

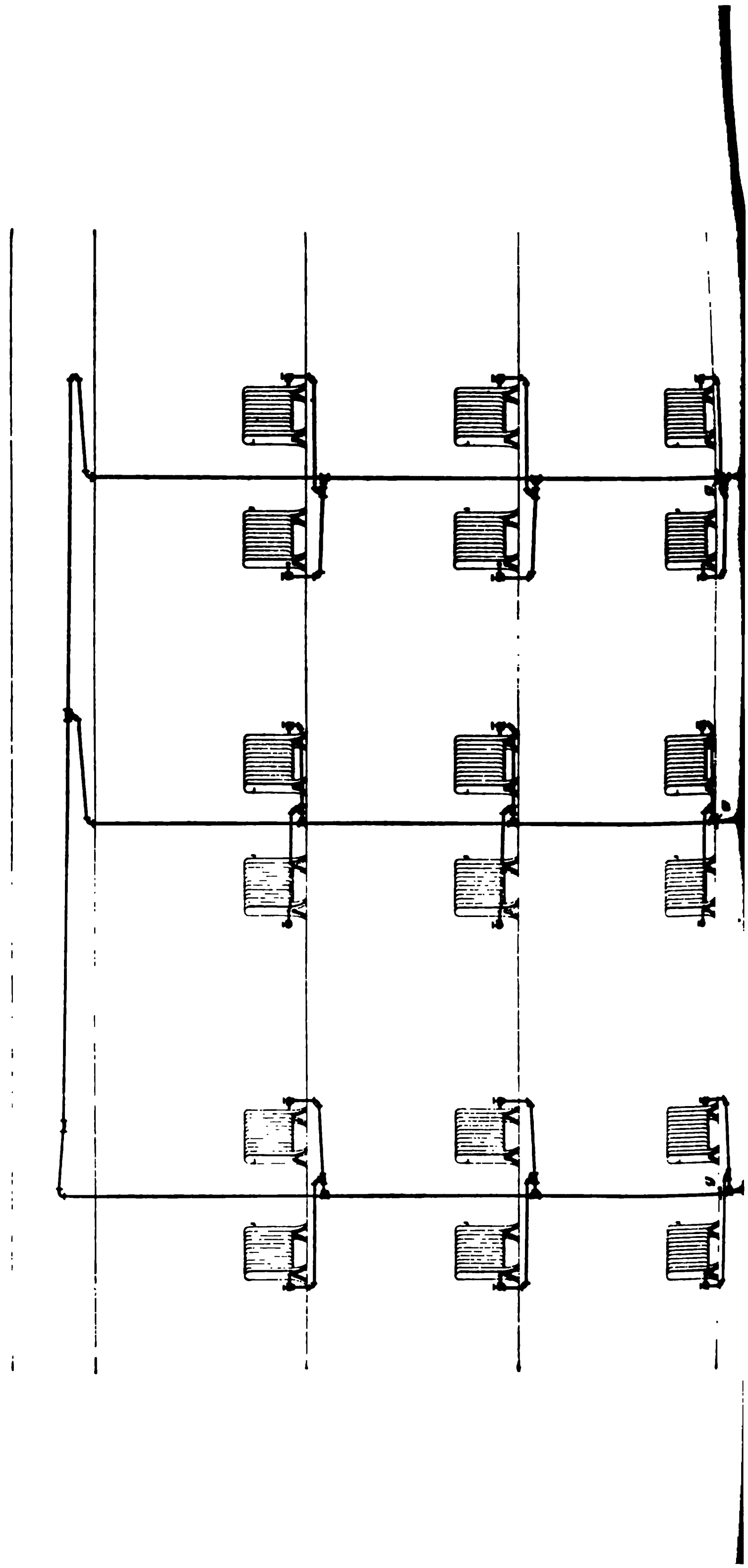
One-pipe connections to radiators and coils should be made only when the steam pressure is not over 5 pounds; the nearer the apparatus can be operated to atmospheric pressure, the less trouble from water hammer will be experienced. Valves for one-pipe work should have renewable disks, so that repairs can be easily and cheaply made.

13. Plans for heating buildings by means of the one-pipe system should be carefully considered, as the success of this form of apparatus depends on the care with which required adaptations are laid out. A combination of the various methods shown may sometimes be used to insure the best results.

14. Down-Feed or Drop-Riser System.—The one-pipe down-feed, or Mills, system of steam distribution is one in which the steam generated by the boiler passes directly upwards through a rising main to a system of distributing mains in the attic or space above the top story, from which drop-riser connections are taken to supply steam to the radiators on the floors below. This system may advantageously be used in large houses having low cellars and in tall buildings wherein the cellar provides rental space of too great value to warrant the installation of the piping of the ordinary types of single-pipe heating apparatus, the drop system requiring less headroom than is necessary for the steam pipe and branches of up-feed systems.

Fig. 13 shows a separate vertical main *a* running to the attic, where the horizontal main supply pipe *b* is located. Branches therefrom are taken to the drop risers *c*, *d*, *e*, and *f*, which are run down below the boiler water-line. The main return pipe *g* may be carried on the side wall or beneath the floor. This method is adopted where the cellar or basement can be used as rental space, or in stores where the space is required for exhibiting or selling goods, the pipes being so arranged as to leave the ceiling free for decoration. The

main supply pipe extends from the boiler to the wall, thence upwards to the attic or top story through a chase, that is, a recess in the wall, in which it is concealed. In the attic, the main horizontal pipe may branch in any direction to connect with the drop risers. The drop riser *f* is connected to but one radiator on the floor beneath, and hence the pipe may be run in the manner shown, the drip from the lower end of the pipe being connected to the drop riser *e*. If a valve is placed in this drop pipe at the top, a similar valve should be placed at the bottom. The valve on the drip pipe should be self-closing, as it is apt to be placed in such a position that it cannot be operated by hand, and hence a check-valve is ordinarily used. The riser *e* is shown as connecting to a single radiator on each floor. The riser is anchored at the center at *h*, so that the pipe above *h* expands upwards and the pipe below *h* expands downwards. The branch connections to the radiators connected to *e* are below the floor and are made with a swivel, so that the movement of the drop riser does not bring any stress on the connections, the elbows of the connecting pipes allowing the movement to be taken up by the tightening or loosening of the threads. The movement is so small where the swivel pipes are of proper length that the joint remains tight for years. If the branch connections were made to crosses in the drop risers, there would be no provision for expansion, which, if upwards, would raise the radiator connection. If the latter was stiff, so that it would not bend, the radiator would be lifted from the floor, and the water of condensation in the radiator would not drain back into the riser. Hence, the use of crosses should as a rule be avoided, though they may be employed when, as at *i*, the connection to the radiator is run above the floor, passing beneath the radiator and connecting, by means of an offset angle valve, at the end of the radiator farthest from the riser. If the pipe is long enough to spring, the radiator will not be lifted up or forced down by the expansion or contraction of the riser. To allow the pipe to drain properly, this method of making the radiator connection requires that the radiators shall have high legs.



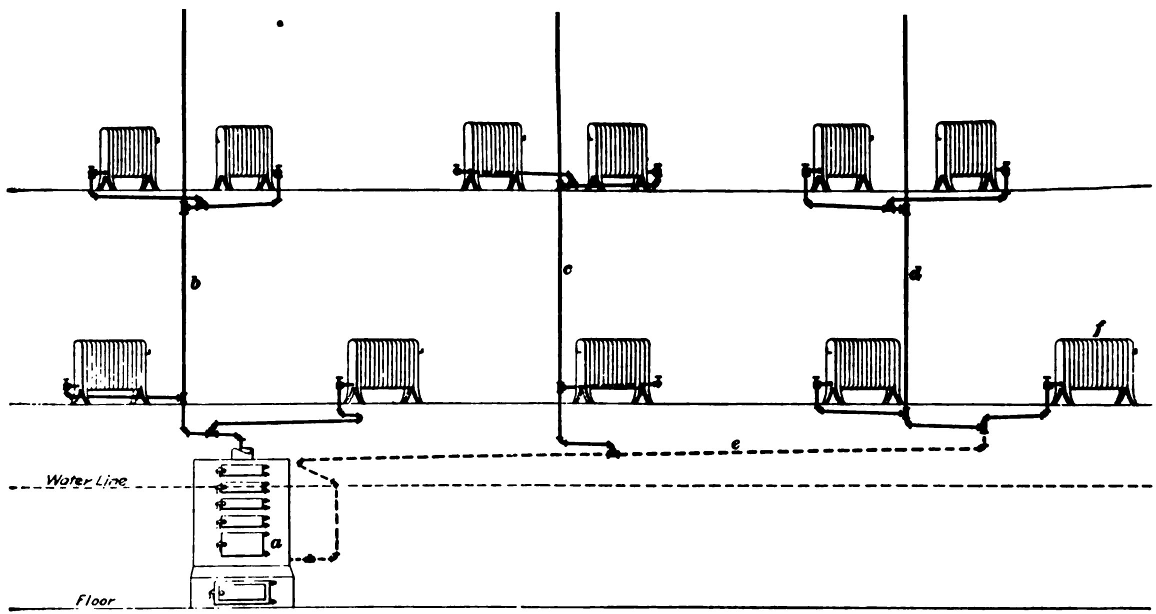


Fig. 14

15. In some cases, the radiator connection is made by means of a short nipple and elbow to a T in the drop riser, the pipe to the radiator being carried back of the radiator, to which the final connection is made by two L's and nipples. The valve can be placed near the riser or at the radiator, where the pipe connects. The rising supply main *a* may be anchored at the center, or it may be supported at the bottom. If supported at the center, expansion is provided for by long horizontal branches or elbow swings at the top and the bottom. If no connections are taken from this riser, it may be secured at the bottom on masonwork, or by a stand at the foot of the pipe. In the latter case, the expansion movement would be upwards, where proper provision for it should be made in the pipe connection to the horizontal main *b*. If the connection between the boiler and the riser is short, the pipe may be graded so that the water of condensation from the rising main will drain to the boiler; but, if the pipe is long, a drip pipe *j* therefrom should be connected into the return main. The extensions of the drop risers below the first floor are called **drip pipes.** Each should have a check-valve where connection is made to the return, especially if there is a valve on the line at the top, as otherwise a considerable amount of water would be drawn up the drop riser by the creation of a partial vacuum due to condensation of the steam by the radiators after closing the valve at the top of the line. The steam valves should be so placed that water will not lodge in them, and horizontal pipes in the attic should drain to the drop risers.

16. Combined Up-Feed and Down-Feed Systems. A modification of the Mills system wherein the radiators on a number of floors are supplied by up-feed piping as well as by down-feed piping, is shown in Fig. 14. Steam from the boiler *a* passes up the riser *b* to the attic of the building, supplying radiators attached thereto by the up-feed system, the balance of the radiators being supplied by drop risers *c* and *d* carried downwards to the basement and there collected into a main return pipe *e* that may be run above or below

the water-line of the boiler. Fig. 14 shows the dry-return system. When a branch to a first-floor radiator *f*, situated as shown, is run, it should be taken from the top of the main return pipe, so that the condensation water will separate from the steam. The risers are usually anchored at the center at *g*. The branches to the radiators are arranged to allow for any movement of the riser or drop pipes due to expansion.

FIG. 15

TWO-PIPE SYSTEMS

17. General Principles. The **two-pipe system** of distributing steam to the several radiators in a building, and of returning it to the boiler in the form of water, so that it may be reheated and redistributed as steam, is essentially composed of a series of pipes that connects the steam space of the boiler to one end of each radiator, and another series that connects the opposite end of each radiator to the water space of the boiler.

It is evident, therefore, that in a two-pipe system of steam heating, each radiator must be connected to two pipes—one of which is the steam inlet and the other the outlet for the water of condensation.

To illustrate the principle of the two-pipe system, arrange an apparatus as shown in Fig. 15. The vessel *a* is partly filled with water, and is heated by a Bunsen burner *b* set under it. The jar *c* is connected to *a* by the tubes *d* and *e*, as shown, and a small petcock *f* has its shank inserted through the stopper of *c*, so that by opening *f* communication is had between the interior of *c* and the atmosphere.

When the apparatus is first set up, the tubes *d* and *e*, the jar *c*, and the space above the water in *a* are all full of air at atmospheric pressure, and *f* is opened. Now light the gas at the burner *b*, and allow the flame to heat the bottom of *a*; the water in *a* will increase in temperature until it reaches the boiling point, which is 212° F. when the pressure is 14.7 pounds per square inch. Steam will then rise from the surface of the water, force the air in *a* through the tube *d* into *c*, and out to the atmosphere through *f*. When the air is thus forced out of *a*, *d*, and *c*, and steam begins to blow through *f*, close *f*, thus making the apparatus steam-tight. The effect of closing *f* is to increase the pressure within the apparatus, because the water is still being converted into steam, and consequently expanding enormously, while the capacity of the apparatus remains unchanged. Now, to prevent the pressure from rising too high and bursting the vessels *a* and *c* or blowing out their stoppers, also to further illustrate the principles involved, arrange a faucet over *c*, and from this faucet allow a stream of cold water to flow over the entire outer surface of *c*. The cold water as it flows over *c* will absorb heat from the steam inside, causing the steam to condense on the inner surface of *c* and flow to the bottom, from where it will fall by gravity through *e* and into the bottom of *a*. It will be observed that if *e* remains unobstructed, and the water of condensation can fall by gravity into *a*, a constant circulation will be going on throughout the apparatus—steam rising in *d* and water falling in *e*. This, then, is the principle of steam circulation by the two-pipe system, and it will be understood more clearly if *a* is assumed to represent a steam boiler, *c* a steam radiator, *d* and *e* the flow and return pipes, respectively, and *f* the radiator air vent.

18. The two-pipe system has certain objections that make it rather undesirable for use in ordinary buildings. The chief objection is that if either radiator valve is closed and the other left open, the water of condensation will accumulate within the radiator, and will cause much annoyance by sending forth noises.

A simple experiment is shown in Fig. 16, in which *a*, which is really a glass jar, represents the boiler, and *b*, which is another glass jar, represents the radiator. The steam pipe is shown at *c*, and the pipe for the return of the water of condensation, or return, is shown at *d*. Place this apparatus in position, and pour water into *b* until the water is at the level *w* in *a* and *d*. Now place the cork in *b*, leaving the air cock *e*, steam valve *f*, and return valve *g* all open; then light the Bunsen burner, applying heat to the water in *a*. When the water boils, the air in *c* and *b* will be forced to the outer atmosphere through *e* by the steam pressure, and steam will fill *c* and *b*. Now let the steam blow freely through *e* for a little while to thoroughly remove all the air from *b*; then close *e*, and reduce the Bunsen flame, so that steam will not generate fast enough to burst the apparatus. A two-pipe gravity circulating apparatus in its simplest form, operating on the principles illustrated in Fig. 15, is now had. If the return valve *g* is closed and the water of condensation thus prevented from returning to *a* by way of *d*, the water will simply collect in *b*, slowly accumulating, and *b* will thereby become flooded. If, when *b* is flooded, *g* is opened, the water in *b* will fall by gravity into *a* and the circulation will proceed as before. Suppose now that *f* is closed, leaving *g* open; the steam supply to *b* will be shut off, and as the steam condenses in *b*, it tends to form a vacuum in this vessel, but the vacuum is prevented by the pressure in *a* forcing water through *d* to fill *b*. This simply means a transfer of water from *a* to *b*,

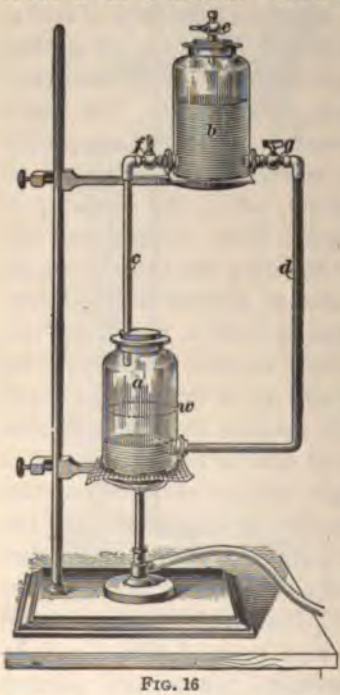


FIG. 16

corresponding lowering of the water-line *w*. Now, occurs in this little experiment when either valve is l, is precisely similar to what will take place when one valves attached to a double-piped radiator is closed e other remains open. In either case the radiator will oded. If the radiator is not very high above the boiler, become rapidly flooded when the steam valve is closed, he water in the boiler may be lowered to a dangerous t.

prevent water in the boiler from being forced by the pressure up the return pipes and into any radiator the steam in it condenses and cannot be replenished other steam, a check-valve, preferably a swing check, e placed on the return main just before it enters the n of the boiler.

Common-Feed and Return System.—There are modifications of the two-pipe system. One is that in riser lines are taken from the steam-distributing main, iser supplying steam to one vertical line of radiators, a ponding return riser being run to accompany each dis- ing riser, and into which all of the radiators of that line mptied, as shown at *B*, Fig. 17. In this figure, the *a* is set in the cellar of the building as usual, and the -distributing main *b* pitches from the boiler, its extreme t end being connected into the return main *c* by the relief *d*. It will be observed in the method of piping the ors *e*, *e*, *e* that the return-radiator connections deliver he same return riser *f* above the water-line. Conse- ly, there is a liability of steam flowing from one radiator nother through the return riser. This is objectionable, se such an inflow of steam to any of the radiators is t the outflow of the water of condensation from the or, and the effect is to back the water into the radiator, us tend to flood it.

Common-Feed and Separate-Return System. a radiator is double-piped, the intention is to have a current of steam and water from the inlet valve to the

outlet valve; that is, an inflow of steam through the inlet and an outflow of water of condensation from the outlet. This object, however, is not always accomplished when the radiators are connected up by the two-pipe method shown at *B*, Fig. 17, because the circulation is not always complete.

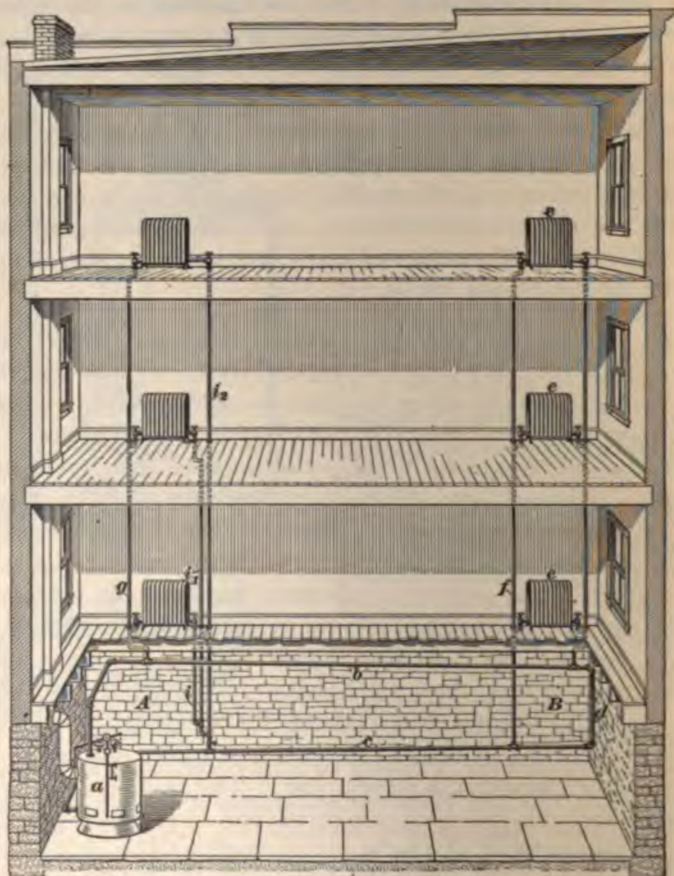


FIG. 17

In order to obtain a positive circulation through the radiators and throughout the system, each vertical line of radiators may be connected to a common distributing riser *g*, from which all the radiators may be supplied with steam, and

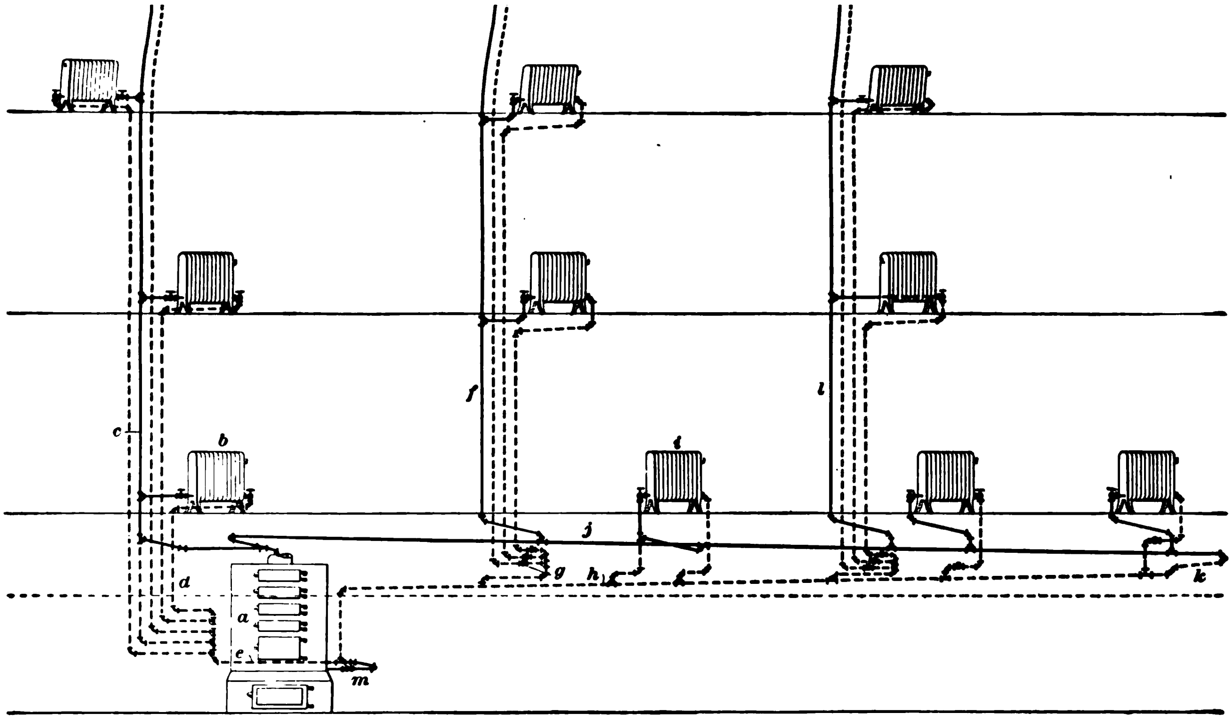


FIG. 18

separate return risers i, i_1, i_2, each running from its radiator to join the return main c at a point below the water-line, as illustrated by the method shown at A, Fig. 17. Since the return pipe to each radiator has no connections made to it above the water-line in the boiler, the flow of steam and water of condensation must be positive, and always in the same direction.

This is the most reliable and most effective method of piping large radiators. It is also probably the most expensive.

21. The general method of installing a common-feed and separate-return system is shown in Fig. 18. In this system, when the valve in the steam-supply radiator connection is partly closed, thereby admitting to the radiator a smaller amount of steam than it would condense under normal conditions, a lowering of the pressure in the radiator through the condensation of the steam therein may result in flooding the radiators on the first floor with water, the water being forced up the return pipe by the boiler pressure in case there is no check-valve on the main return pipe near the boiler, or, in cases where the main return pipe is fitted with a check-valve, the water might accumulate in the return pipe and flood the radiator before a sufficient hydrostatic head had been attained to force the water into the boiler. No such trouble is liable to be experienced with radiators on the upper floor, because the boiler pressure usually carried is not high enough nor the vacuum of sufficient extent to force the water back into them.

To illustrate, let it be assumed that there is no check-valve in the return main near the boiler and that the pressure on the boiler a is 2 pounds; furthermore, let the first radiator b on the riser c be 46 inches above the boiler water-line. This height is such that a pressure of nearly 2 pounds will be necessary to force the water of condensation in the return pipe d into the radiator. If the valve in the steam connection to b is partly closed, the air valve being open, the pressure of the steam that flows into the radiator and condenses will be lowered by the restriction of the valve opening. Assuming

that the pressure falls to that of the atmosphere, air and steam occupy the radiator in proportion to the amount of surface that absorbs the heat from the steam. The water of condensation falls by gravity to the return outlet of the radiator and thence through the return pipe *d* to the main return *e*. The pressure in the boiler will maintain the water in the return pipe *d* at a height corresponding to the pressure in the return main. Should a pressure greater than 2 pounds exist in the main steam and return pipes, the water would be forced into the radiator *b* and shut off the restricted opening of the valve in its steam connection. The resulting conflict between steam and water would cause water hammer.

The returns from the radiation at the left of the boiler are brought together below the water-line, as shown. The riser *f* feeds its first radiator on a floor higher than that fed by the riser *c*, and the return pipes drop into a manifold in the cellar above the water-line of the boiler. These return pipes are provided with check-valves at *g*, so as to seal the return pipes and thereby prevent steam from passing up through them, but the check-valves also prevent the return water from passing out of the return pipes until the amount of water that accumulates in them is heavy enough to force the valves open against the pressure in the dry return main *h*. It is evident that the three radiators on this line might be operated at different pressures below that carried on the main steam pipe. The position of the radiators on the first floor with reference to the boiler water-line governs the pressure that may be carried on such a system, and the closer the radiators are to the boiler, the lower the pressure must be. The connection to the radiator *i* from the steam main *j* should not be restricted, as the steam and return pipes should be in perfect balance to give satisfactory results. Where there is no attempt at restricting the opening of the radiator valves, and the pipes and valves are properly proportioned, this system may be used for low-pressure heating and operated with one valve on the supply connection to the radiator, provided that the height of the lowest radiator above the water-line is sufficient to insure

the necessary hydrostatic head to cause the water of condensation to flow into the boiler. If higher pressures are to be used, the return pipes must be carried below the water-line in the boiler, and the pipes should have check-valves in them, as shown at *g*.

22. Fig. 18 shows two systems of return mains and return pipes from radiators, which are the wet-main and the dry-main systems. The wet-return system should be employed as the safer of the two. Without careful planning, the installation of the dry-return system should not be attempted.

In the dry-return system, the main steam pipe extends from the boiler to the ceiling, branching to the right to supply risers and radiators. At the branch to the radiator *i*, the main is reduced; the branch is taken from the bottom of the main and drains into the return pipe *h*. The steam main *j* continues to the end of the run and a drip *k* is connected to the return main, which follows the wall above the boiler water-line. The return pipes from the radiators on the upper floors discharge into the return main, and the relief pipe at *k* drains the water of condensation from the main steam pipe into the return main. The return pipes from the radiators connected to the risers *f* and *l* drop separately to manifolds that are connected to the main return by a pipe connected into the top of the return main. Each radiator return pipe should have a check-valve to seal the connection; a radiator valve will then be required only in the steam-supply radiator connection. The condensation from the radiation accumulates in the return and above the check-valve until there is sufficient head of water to open the valve and discharge the water into the return main. The steam main at the left is shown connected to one riser only, but it could be extended as required. The branch to the riser *c* is taken from the end and drains the main at the left by means of a drip pipe connected to the riser and draining into the manifold below the boiler water-line; hence, the return at the left is a wet return. A check-valve *m* is placed in the main return near the boiler.

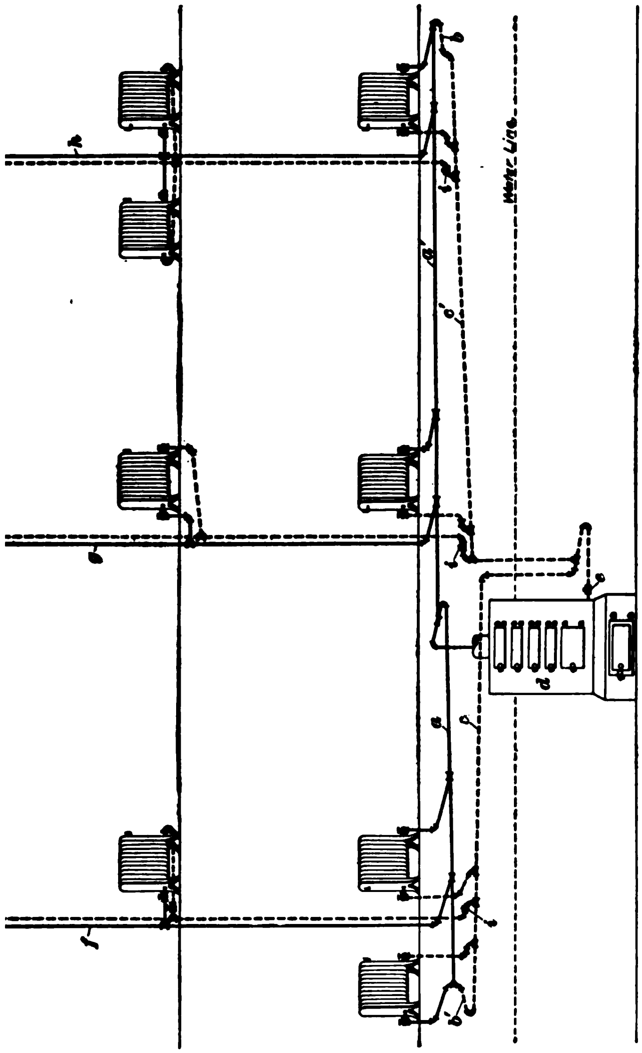


Fig 19.

For very low-pressure work, the return pipes from the radiators may be installed without check-valves, but where the pressure is fluctuating, each first-story radiator should have a check-valve in the return pipe. The supply connections should be provided with valves for hand operation. The return connections may also have hand valves if desired. Automatic air valves are necessary to secure success with this system, for if the radiator valve were closed and air were not admitted to the radiator, the condensation of steam in the radiator would cause the pressure in it to fall below that of the atmosphere, and the water in the return pipe might be lifted into the radiator if there were no check-valve in the radiator return pipe. It is also evident that if one radiator in a sealed-return system condenses steam faster than another, the pressure in that radiator may be lowered, and therefore the water in the connecting return pipe will stand at a higher level. In the main return to the boiler, the water of condensation will flow intermittently, thereby causing a fluctuation in the water-line of the boiler. With the dry-return pipe the fluctuation in the rising pipes does not affect the radiators that are connected to the main independently, but the fluctuation in the boiler will be the same.

23. **Balanced Dry-Return Main System.**—Fig. 19 illustrates a piping system of the balanced dry-return main type. The main steam pipe rises from the boiler and branches as desired. The mains *a*, *a'* are of one size to the end, where a balancing relief or drip pipe, as *b*, *b'*, connects to the main return pipe *c*, *c'*. The main return pipe is usually one size smaller than the main steam pipe. The return main *c*, *c'* drops near the boiler *d*, to which it connects below the water-line, a check-valve being placed at *e*. The risers *f*, *g*, and *h* are connected to the main at the side or top, and the condensation in the risers drains into and flows to the ends of the steam main and thence through the drips *b*, *b'* into the return mains *c*, *c'*. The radiator connections are shown as being made in various ways, either above

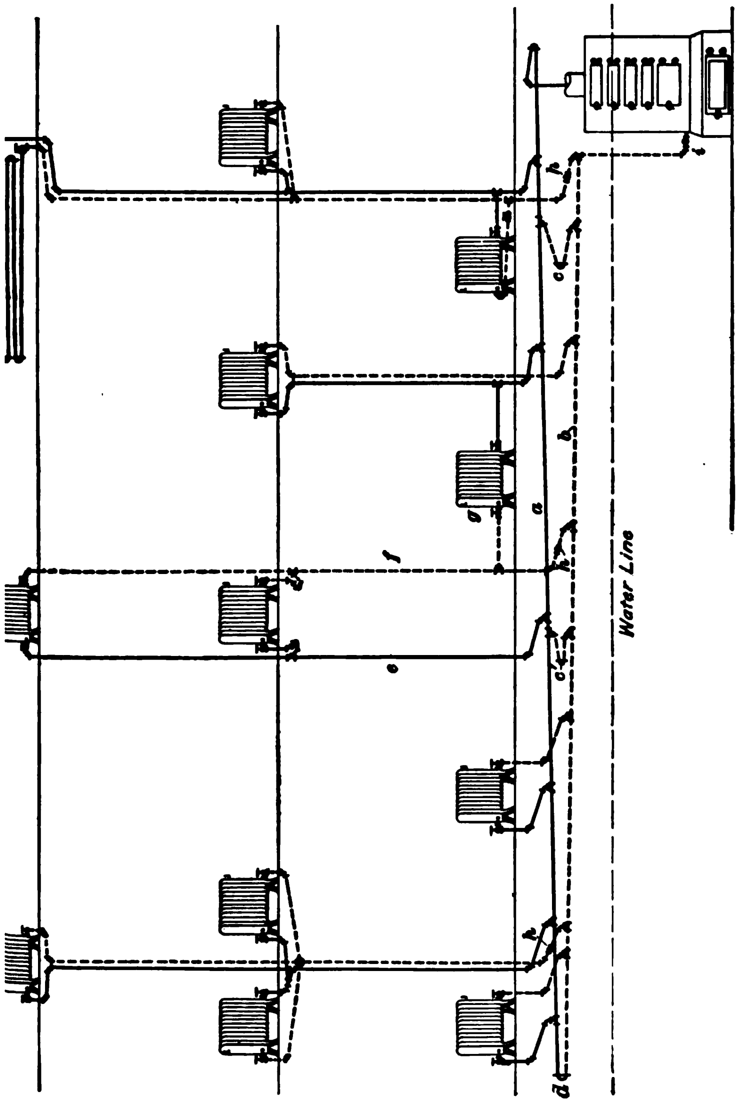


FIG. 20

or under the floor, as may be most convenient. The radiator-return connections are similar to the steam-supply connections. Each return riser connects into the top of the return main. The radiators for the first floor are usually connected directly to the main. The mains are graded in the direction of the flow of the liquid and should be in perfect balance; that is, have the same pressure in them. It is evident that steam will be in both steam and return mains, and if the air valves on the radiators allow the air to discharge quickly, the steam in the return pipe may be forced into the return end of the radiator and close the air valve before the rest of the radiator warms, leaving air in the middle of the radiator and preventing the radiator from doing its work. To overcome this difficulty, the return pipes may be arranged with check-valves *i*, *i*. The drip pipes from the ends of the mains provide for an equalization or balancing of pressure in the steam and return mains. Each radiator connection should be provided with a valve, and in shutting off the radiator, the return valve should be closed first, while in turning on steam, the steam valve should be opened before the return valve is opened.

24. Fig. 20 shows a balanced dry-return system, with balance pipes that allow the steam main *a* to be reduced in size toward the end. The mains are shown extending in one circuit, with the return main *b* hung directly beneath the steam main. The steam pipes for this system should be proportioned so that the steam main will supply the radiators without a great loss by friction in the pipes. The branches to risers and first-story radiators may be taken from the top or side of the main, as required. At each reduction in the steam main, a balance pipe, as *c*, *c'*, should be connected to the return main. These balance pipes serve to maintain the same pressure in the steam and return mains. To allow for the expansion and contraction of the pipes, the balance pipes are carried outwards a short distance from the steam main, and then return and connect into the return main. The drip pipe *d* may be offset in the same

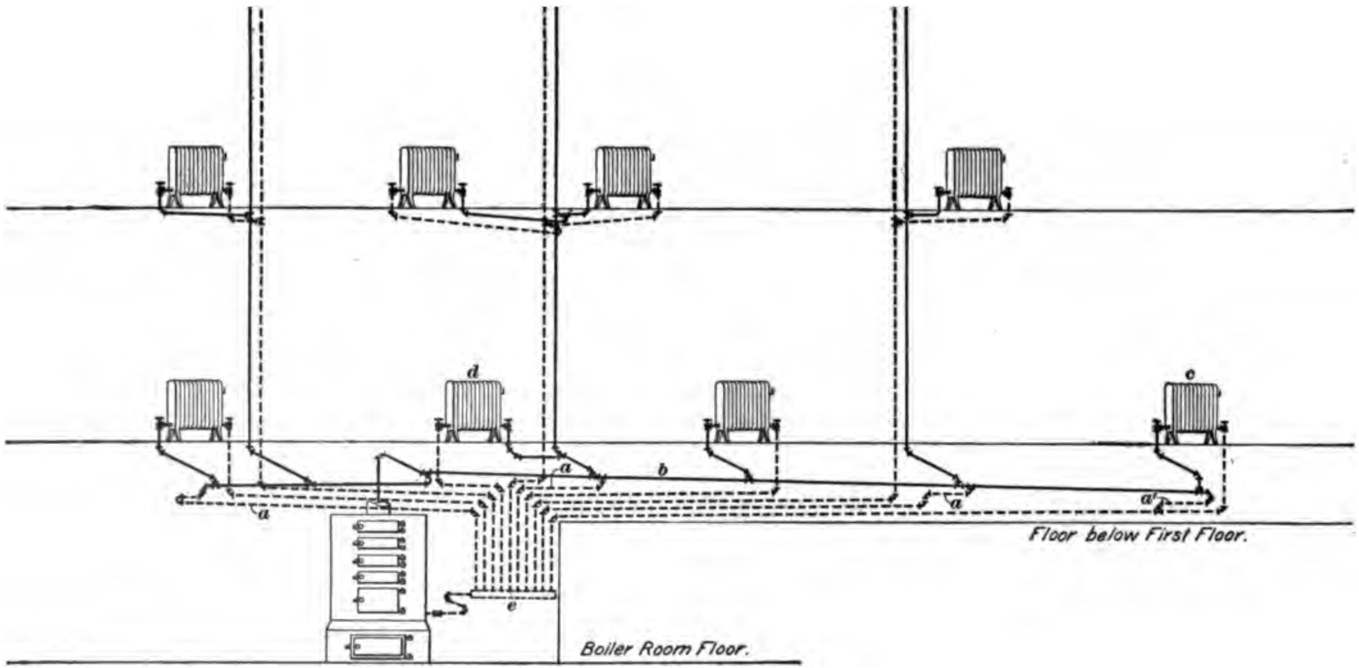


FIG. 21

manner if the pipe is long; but if short, it may be taken from the end of the main, as shown. The riser *e* and return *f* are run in a manner somewhat different from those previously shown, the steam pipe *e* passing up at one end of the radiators and the return *f* at the other. Radiators, as *g*, are sometimes connected at one end to the steam riser of one group of radiators and at the other end to the return riser of a different group of radiators. Such connections should be avoided, however, as they tend to cause unequal pressures in the risers. The return risers should be provided with check-valves, as *h*, *h*. A check-valve *i* should be placed in the return main.

25. Sealed Dry-Return System.—With a system of sealed dry returns and drip pipes, such as is illustrated by Fig. 21, the boiler is located at a lower level than the space in which the return pipes must be carried, so that the return pipes run above the boiler water-line to a point near the boiler, where they are connected into a main header or return pipe below the boiler water-line. The main steam pipe branches off to the right and left, and is reduced in size as branch riser connections are taken therefrom. At points of reduction of the main, balance pipes *a*, *a* drop and branch to the side wall, then run to the point at which they are to connect to the manifold below the water-line. At the end of the main *b* is a steam connection to a radiator *c* on the first floor. If the pipes are of sufficient size, the pressure at this point will be so nearly balanced in the connection that the balance pipe a' serving as a drip pipe can be connected to the return pipe from the radiator. The steam connection to the first-floor radiator *d* is shown as branching from a riser connection. This may be done if the pipes are of ample size to supply the amount of radiation connected with them. The return branch from the radiator *d* may be connected to the manifold *e*, as shown, or to the return riser below the boiler water-line. Fig. 21 shows the radiators connected to the risers by branches run beneath the flooring. The connections under the floor should provide for taking up the expansion and

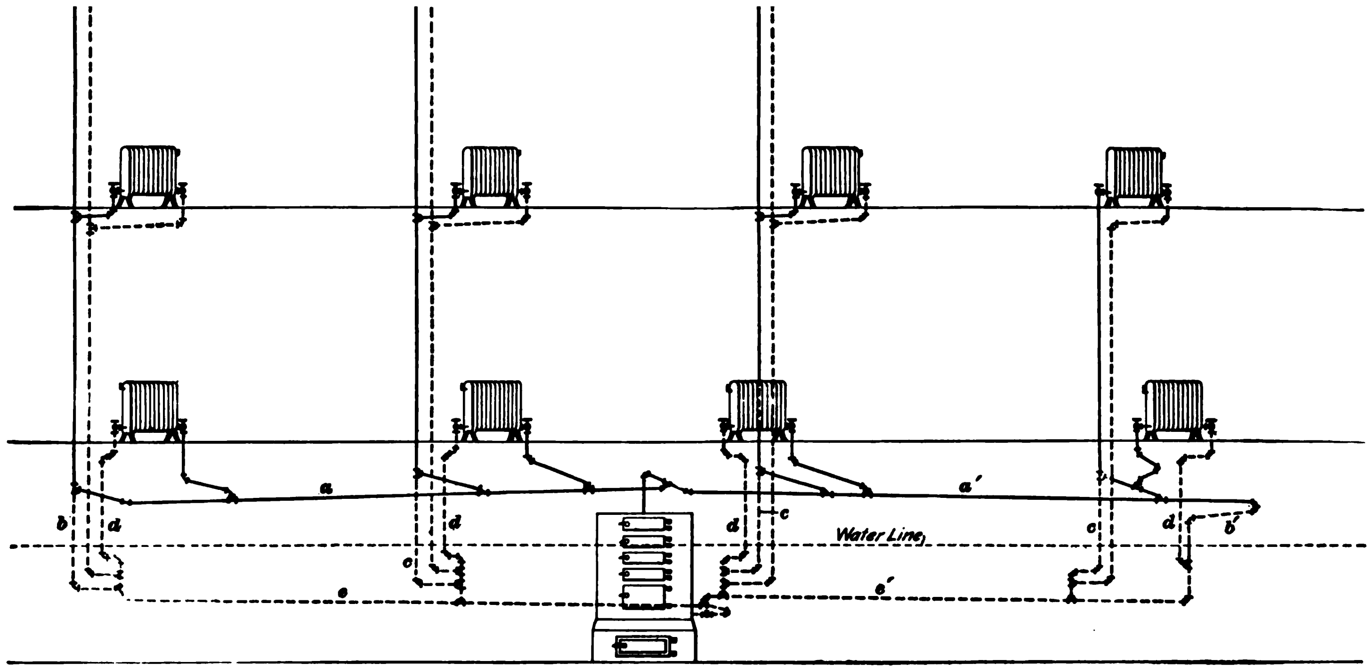


Fig. 22

contraction by swing, or swivel, joints, formed by using nipples and elbows. Pipes under the floor that run through beams should be covered with tin or sheet-iron tubes, so that the pipe will be kept clear of woodwork.

26. Dripped Riser System.—An illustration of the dripped riser system is presented in Fig. 22. The main steam pipes *a*, *a'* pitch toward the end, where the drip pipes *b*, *b'* relieve them of condensation. The main branches *a*, *a'* would have to be run full size to the end unless provision were made to relieve them of water at intermediate points. The riser connections being taken from the side of the main, the latter is drained by the relief pipes *c*, *c* at the foot of the risers. The riser branches could be pitched toward the main if eccentric reducing **T**'s were used on the run, so that the mains would drain to the ends. As the branches to the risers are short, there will be little condensation in them, but condensation in the risers will be considerable, and the drip *c* connected to the bottom of each riser drains the condensation into the main return. The drip pipes are carried below the boiler water-line and are therefore sealed. The return connections *d*, *d* from the radiators on the first floor are also carried below the water-line and thus sealed. The drip and return pipes are connected to the return main *e*, *e'* in such a manner as to allow for the expansion of the pipes. As the main return follows the wall, the pipes dropping to it would be rigid if connected to the main without spring pieces, and the connections would be hard to make and keep tight.

27. The riser connections of the piping system illustrated in Fig. 22 are shown as being taken from the top of the main. Fig. 23 shows the branch connections to the risers taken from the bottom of the main *a* in such a manner as to obviate the need of special main drip pipes at points where reductions are made in the size of the main. The branch connections to the main should be large and pitch toward the foot of the riser, so that the water of condensation will not interfere with the flow of steam. A large drip pocket should be provided at the foot of each riser, the drip pipe dropping into the return main *b*

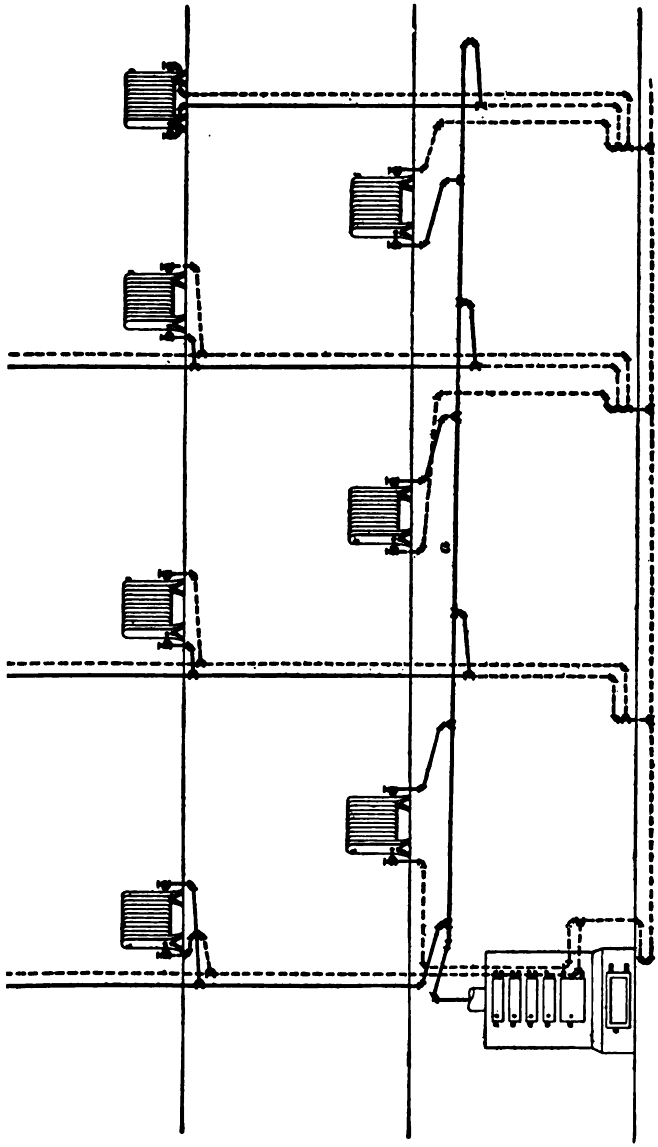


FIG. 23

below the boiler water-line. The return main is shown as being carried under the floor, but it may be run at any convenient point above the floor below the boiler water-line.

If valves are placed in the branch connections to the risers in the system illustrated in Fig. 22, there should be a corresponding valve in each return riser, and the drip pipe connected to the foot of the riser should also be provided with a valve. The system shown in Fig. 23, however, requires that valves be placed only in the vertical riser and return. The system shown in Fig. 22 is the one commonly used. The actual installation of heating apparatus frequently requires that a combination of the systems shown in Figs. 22 and 23 be used, as the ceiling of the cellar in which the main is erected may have some beam that will not allow the connection to be taken from the top of the main. In such cases, the system shown in Fig. 23 can be used to advantage. The bottom branch connections are brought nearer to the boiler water-line, however, and hence if the water in the boiler fluctuates to any extent, the water may be forced into the riser and cause water hammer. In erecting this type of apparatus, therefore, the branches should be as far as possible above the boiler water-line.

28. **Two-Pipe Down-Feed System.**—Fig. 24 illustrates the down-feed system with return pipes. This system is erected in the same manner as the single-pipe down-feed system shown in Fig. 13, except that the radiators are connected at the return end into drop return pipes, by which they are drained. The return mains may be carried back to the boiler in two ways, as indicated. The return pipes *a* and *b* drop into a dry-return pipe *c* carried near the ceiling, or at the side wall above the boiler, dropping at some convenient point to make connection with the boiler. The return pipes *d* and *e* drop into the return main *f* beneath the cellar floor and below the boiler water-line. Either method may be used.

The steam drop pipe *g* supplies two radiators on floors nearest to the horizontal attic main, and, as no more connections are required on this line, the pipe may be discontinued

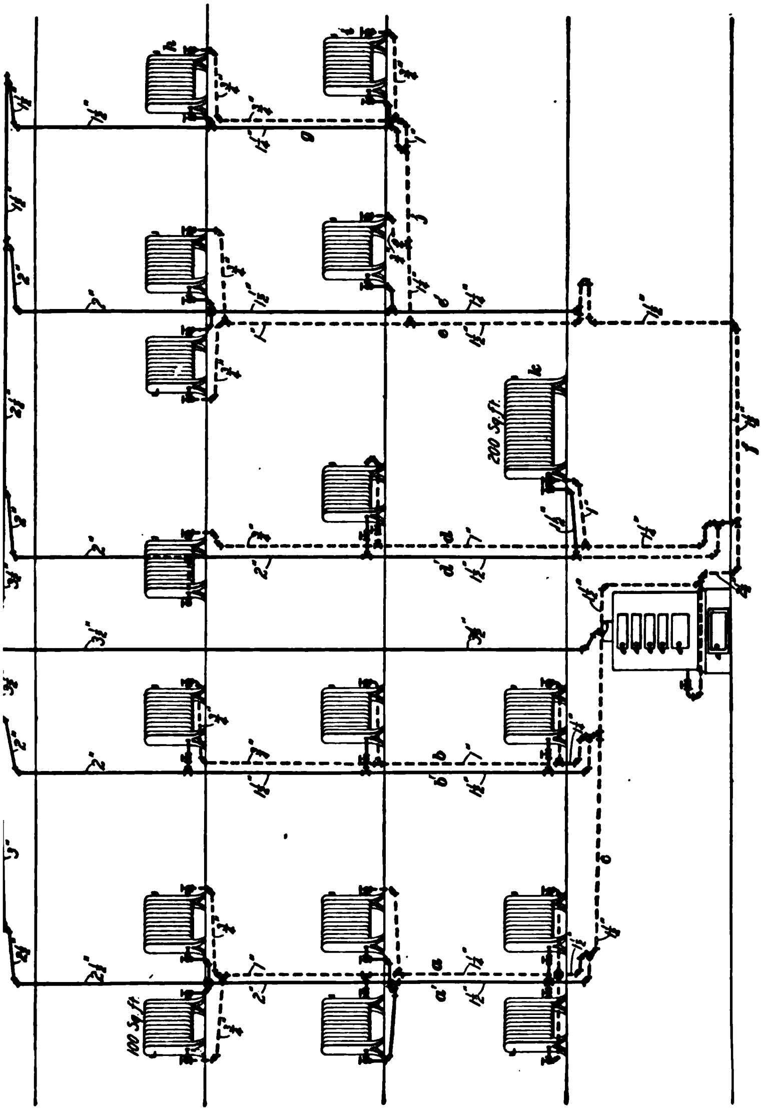


FIG 24

at the point shown, the bottom of the pipe being dripped into the return connection from the radiators *h* and *i*. The return connections of the radiators *h* and *i* on this line, as well as the drip at the foot thereof, drain into a separate return *j* carried along the ceiling to the next drop return pipe *e*. If the drop riser *g* has a valve, the return *j* should also have a valve near the connection of the steam-pipe drip. To allow for expansion, the return pipe *e* is provided with an offset at the ceiling line of the cellar, where the pipe drops vertically into the return main, as shown. If the pipe were run straight down into the return pipe, the expansion would be upwards and the radiator connections would be raised so much that the water of condensation would not flow through them; the final connection to the return main would be difficult to make. The return drops *a* and *b* are shown offset where they connect to the return main, as is also the drip from each drop steam pipe, which provides for expansion and easy means of making final connections. The radiators are connected in various ways, similar to those shown with the up-feed systems. The steam and return pipes connecting into the radiator *k* are shown at the same end. In some makes of radiators, the base is divided so that separate steam and return passages are formed, but the ordinary type of sectional radiators have but one opening through the base. To connect two pipes to the same end of an ordinary radiator is therefore equivalent to a single-pipe connection. This method is, in fact, a detriment to the circulation, as the steam short-circuits and impedes the discharge of air from the radiator.

29. An apparatus of the type shown in Fig. 24 may be used very effectively in high buildings and factories, or where the headroom of the basement is low, or where the space is to be rented, and a network of pipe must not interfere with the decoration. Long runs under floors to radiators should be avoided as much as possible. The radiator connections to the risers should be large, because water of condensation, as well as steam, flows down the drop pipes.

[he water does not impede the flow of steam, as it does in he up-feed system, but the steam is liable to flow past the adiator connection openings if they are small. In designng this type of system, the reduction in sizes of the drop ipes as the pipes descend must be made gradually, to preent the steam that passes to the radiator from carrying ondensation with it. The return pipes may be much maller with this system than in others. The dry-return nain should be larger than the wet-return main, so that here will be an equal pressure in all the drop pipes. Where alves are placed in the steam pipes, there must be correponding valves in the return pipes; the latter may be of he check-valve or gate-valve pattern. Drip pipes also hould have valves when the steam lines to which they onnect have valves.

30. As with other methods of piping buildings, the area f each supply pipe for the overhead or drop-feed system hould be proportioned according to the amount of radiating urface to be supplied by the pipe, the size of the return pipe lepending on the amount of condensation to be carried away, s determined by the amount of steam delivered to the adiating surface that it drains.

Sometimes the main return pipe of large drop-feed heatng systems, by being run dry, is made to serve as the vapor r breathing pipe of the system by tapping into it beyond he return trap and running a breathing pipe to the atmoshere. When steam is turned on in the morning, assuming t to have been turned off during the night, a gate valve in he breathing pipe is opened and the air in the system is orced out through the vapor pipe until the apparatus is horoughly heated, when, by partly closing the valve, the hrottled gate valve and attached breathing pipe become he air valve for the entire system.

In other cases, the returns are discharged in the baseent into a drip tank from which the breathing pipe that erves as the air valve for the system is carried to the tmosphere.

31. In proportioning the piping for two-pipe drop-feed systems, such as are frequently installed in office and other large buildings, where exhaust steam, occasionally supplemented by live steam, is used for heating purposes, and where the limit of pressure is fixed at 2 pounds, the factors given below may be employed with satisfactory results. Under average conditions the pressure carried on such systems seldom exceeds 1 pound, and the pipe sizes required may be computed by multiplying the number of square feet of radiating surface to be served by each pipe by the following factors to get the area of the pipe, in square inches: Main supply riser, .005; attic mains and drop risers, .009; radiator supply connections, .012; radiator return connections and return risers, .003; main return in cellar, .001. It should be borne in mind, however, that the radiator supply connection should never be less than 1 inch, the radiator return connection less than $\frac{3}{4}$ inch, or the drop risers less than $1\frac{1}{4}$ inches. The main return pipes in the basement should be proportioned for taking care of the condensation from the total radiation in the building.

EXAMPLE.—What should be the sizes of the main supply riser, attic mains, drop risers, radiator supply and return connections, and main return for the two-pipe drop-feed heating system illustrated in Fig. 24, where the drop risers a', b', d', e', and g serve 600, 300, 400, 300 and 200 square feet of direct radiation, respectively?

SOLUTION.—Altogether there are seventeen radiators having $600 + 300 + 400 + 300 + 200 = 1{,}800$ sq. ft. of surface; hence, the area of the main supply riser should be $.005 \times 1{,}800 = 9$ sq. in., corresponding to which the nearest standard pipe size is $3\frac{1}{2}$ in. To the two drop risers a' and b' are connected nine radiators having $600 + 300 = 900$ sq. ft. of surface; therefore, the area of the attic main between the main supply riser and the branch connection to the first drop riser b' should be $.009 \times 900 = 8.1$ sq. in., while the area of the attic main from the first to the second branch connection to the drop riser a' should be $.009 \times 600 = 5.4$ sq. in. Since the nearest corresponding standard pipe sizes are $3\frac{1}{2}$ in. and 3 in., respectively, the attic main would be of the same size as the main supply riser up to the first branch connection to the drop riser b', at which point it should be reduced to 3 in. to supply the drop riser a'. To the drop risers d', e', and g are connected eight radiators having $400 + 300 + 200 = 900$ sq. ft. of surface, and hence the attic main, as at the left, should be $3\frac{1}{2}$ in. up to the branch

ection to the drop riser d', at which point it should be reduced so the area of the main would be $.009 \times 500 = 4.5$ sq. in. This area nearly corresponds to that of a pipe $2\frac{1}{2}$ in. in diameter. The attic between the branch connections to the drop risers e' and g, since 00 ft. of radiation is served thereby, should have an area of .009 0 = 1.8 sq. in., corresponding most nearly to a pipe $1\frac{1}{2}$ in. in eter. The size of the branch connections between the attic main the drop risers being dependent on the amount of radiation to be lied, their respective areas are found by multiplying .009 by the int of radiation attached to each drop riser. Thus, the branch ection to the drop riser a' should have an area of $.009 \times 600 = 5.4$ 1.; to drop riser b', $.009 \times 300 = 2.7$ sq. in.; to riser d', $.009 \times 400$ 6 sq. in.; to riser e', $.009 \times 300 = 2.7$ sq. in.; to drop riser g, .009 0 = 1.8 sq. in. The nearest standard pipe sizes corresponding to areas are $2\frac{1}{2}$, 2, and $1\frac{1}{2}$ in., respectively. Between the branch ection to the attic main and the first radiator connections taken the drop risers are necessarily of the same size as the branch conions to the attic main, as indicated in Fig. 24. After the first ator connections are taken off, however, the size of the drop riser adually reduced, practically in direct proportion to the reduction e amount of radiation to be supplied, except that a supply riser ller than $1\frac{1}{4}$ in. should not be used. The area of the radiator conions should be $.012 \times 100 = 1.2$ sq. in., which corresponds most rly to that of a pipe $1\frac{1}{4}$ in. in diameter. The corresponding return nections should have an area of $.003 \times 100 = .3$, or a diameter of . Smaller piping than $\frac{3}{4}$ in. should not, however, be used because he liability of chokage and injury by bending. Since the return rs, as in the ordinary type of up-feed gravity heating system, ald be proportioned according to the amount of radiation from ch they drain the water of condensation, satisfactory results will be ined when the area of the return risers is made .003 sq. in. per ft. of radiation supplied. Thus, the area of the return riser a ld be, progressively, $.003 \times 200 = .6$ sq. in.; $.003 \times 400 = 1.2$ sq. in.; $\times 600 = 1.8$ sq. in. As there are two $\frac{3}{4}$-inch radiator branches harging into the return riser a at the top, it should be started 1 in. liameter, increasing to $1\frac{1}{4}$ in. after the second pair of radiator contions are made to it, and finally to $1\frac{1}{2}$ in., as indicated in Fig. 24. main return pipes c and f in the basement should have an area of $\times$ 1,800 = 1.8 sq. in., or a diameter of $1\frac{1}{2}$ in. Ans.

2. While the proportions given in the illustrative mple are such as would give perfectly satisfactory results ieating, it may be stated, in explanation of the fact that dimensions of the piping vary somewhat from the calated values obtained by using the coefficients above

presented, that the factors given apply particularly to the large piping systems of office and other public buildings, wherein the amount of radiation supplied varies from 5,000 to 50,000 square feet or more of radiating surface.

FACTORY PIPING SYSTEMS

33. The usual custom in factory heating is to distribute the heat by means of pipe coils arranged, as far as may be practicable, around the walls of the room or hung from ceilings, where the heating surface is out of the way. When the boiler *a*, Fig. 25, is on the level of the first story to be warmed, the coils must be kept above the boiler, in order that the water of condensation may return to the boiler by gravity. In most buildings of this class, however, pumping machinery is available for use in forcing a return of the water of condensation back to the boiler. The coils for the upper stories are run around the side walls, as shown. Any number of coils, erected in a similar manner, may be placed as required, to warm the room. The coils *b*, *b'* are made with spring pieces connected into a manifold *c* at the steam end, as shown. The pipes are supported in hangers at a distance of about 12 inches from the ceiling beams, and are graded toward the return end, where another manifold *d* connects them and receives the condensed water. At this point, a connection is made with the return pipe *e*. The wall coils *f* and *f'* are similarly connected to the steam and return pipes. The steam main rises from the boiler and branches to supply the risers *g* and *h*. These branches may be taken from the top or side of the main, as shown. At two points, the branches for the coils on the first-floor ceiling are connected into the main. As the main is run below the coil, the branch connection to the coil is taken from the top of the main and carried over to connect to the coil. The elbows in these connections allow for expansion, the main being free to move without placing any stress on the coil connection. The branch connection to the riser *g* is made to the top of the main, so that the pipe is free to swing on the joints of the elbow at

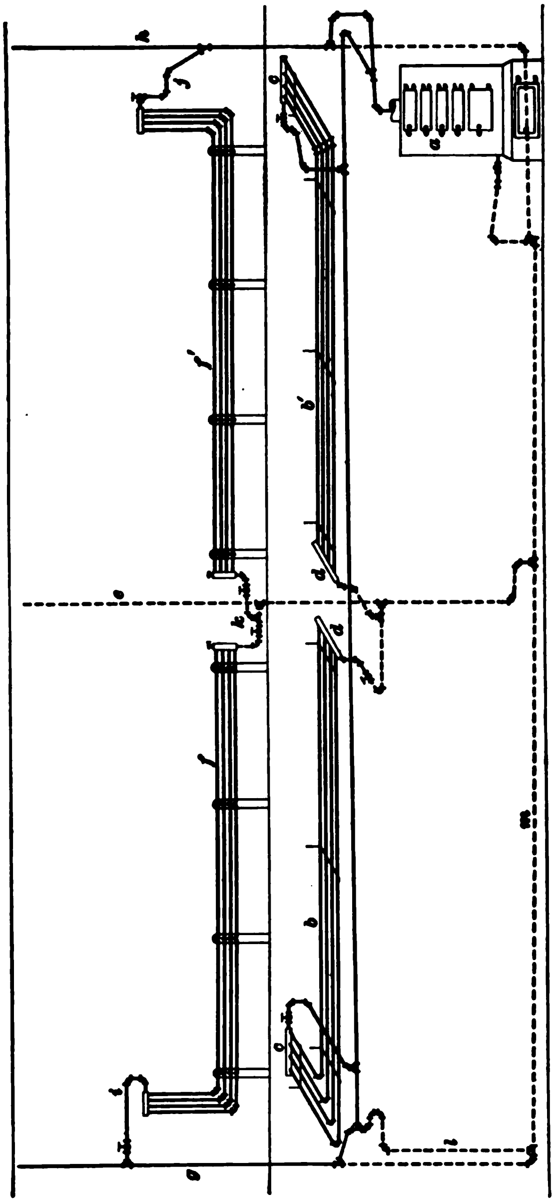


FIG. 25

the top of the main and the bottom of the riser. This method is also shown in the connection to the riser h. The connection i to the coil on the second floor shows a method of allowing for the expansion of the riser. The coil spring pieces that provide for expansion are proportioned to the length of the coil. The connection j to the coil f' is made to the riser below the coil inlet, elbows and nipples being used to form a swing in the connection to provide for expansion. The return pipes are brought together into the same return [illegible], as shown at k, connecting to the riser and the [illegible]o a **T** in the other branch. The coils are abo[illegible]ranches, which are connected to a **T** in the ris[illegible] provided to allow for lateral expansion, and [illegible]re long enough, the vertical expansion [illegible]by the spring of the pipe; if the branch is [illegible]uld be put in to form swing joints. The return [illegible]ects to the top of the main return by a spri[illegible] allows for the expansion of the pipe. The ma[illegible]pe is of one size to the end, where a drip pipe l c[illegible]with the main return. If the steam main were reduced, there would be a drip pipe at each reduction. Drip pipes are also provided at the foot of the risers. The main return pipe m is placed at the wall, or it may be run at any convenient point below the boiler water-line. If necessary, the main return could be carried above the boiler water-line, as previously described and illustrated in connection with other systems, but, where possible, it is advisable to seal the return pipes in factory heating systems of this kind. Each coil should be provided with a good automatic air valve, as the ordinary air cock requires constant attention. Automatic air valves give much better service.

INDIRECT AND SEMIDIRECT HEATING SYSTEMS

GENERAL CONSTRUCTION

34. Indirect Heating System.—Indirect steam heating is a method of warming buildings by steam, in which the heating surfaces, or indirect radiators, are located outside of the rooms to be warmed, communication being had between the rooms and their respective radiators by means of large air conduits, commonly called *hot-air ducts.* By using this system of warming buildings, the radiators are not open to view, as are direct radiators, but are entirely concealed; they are usually located in the cellars or basements of the buildings, and are completely incased by boxing of some material that is a non-conductor of heat. It is customary to incase each indirect radiator separately, using the radiator for a partition, as it were, to divide the box into two compartments or chambers—an upper and a lower one. The upper chamber communicates with the room to be warmed by means of the hot-air duct, and the lower chamber communicates with the outer atmosphere by means of another conduit, commonly called the *cold-air duct.* Since the sections that constitute the entire radiator are spaced some distance apart, the air in the box, being heated by the radiator, will rise through the hot-air duct and flow into the room, cold air from the outer atmosphere replacing it. It will thus be seen that, by the indirect method of warming buildings, ventilation as well as heat is secured.

35. Fig. 26 shows how indirect radiators are commonly arranged to warm rooms on the ground floor. The radiator *a* is set in the middle of its casing, or box, and is suspended by iron hangers from the joists of the floor above. Steam enters the top of one of the end sections by the pipe shown, and leaves the radiator by a return pipe, not shown. Fresh air enters through the register face, or grille-work, which is secured over the mouth of the cold-air inlet duct *b*, made flush with the face of the wall, and passes through the radiator into the hot-air duct *c*, and then into the room

above through a floor register *e*, as shown by the arrows. This arrangement of the heating surface is such that the room cannot be warmed without ventilation. If the radiator box were furnished with another inlet duct that would take a supply of air from the floor of the room, the room could be warmed without ventilation. This, however, in many respects is objectionable, because the same air is heated and reheated, breathed and rebreathed, and soon becomes vitiated, if the room is occupied. The hot-air duct is taken from the side of the casing and is furnished with a flat bottom. This is particularly advantageous for floor-register connections, because any sweepings from the floor that may

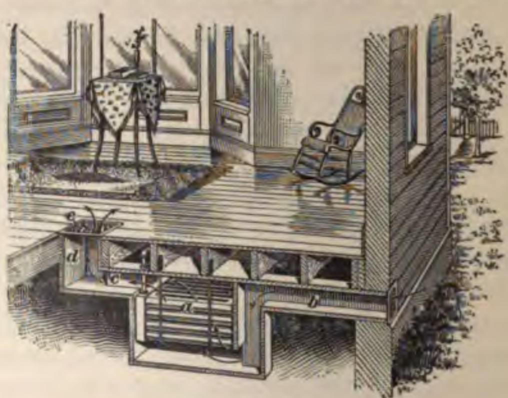


FIG. 26

fall through the register will accumulate in the bottom of *d*, and can easily be removed by simply lifting out the register; it prevents the dirt from falling on the radiator and clinging to the castings, from which it will be carried up into the room in the form of fine dust.

Indirect radiators are often made to deliver hot air into the rooms from wall registers located at different heights from the floors. Sometimes these wall registers deliver quite close to the floor, and at other times quite close to the ceiling. The proper point of delivery will depend on circumstances, such, for instance, as the outlet orifices from the room and the velocity at which the air enters the room.

36. Semidirect Heating System.—The semidirect, so called the *direct-indirect*, system of heating consists in acing radiators in front of windows, or at other points, d making a connection with the outside air by means of icts leading to the base of the radiators, in which dampers e placed for shutting off the outside air. This provides r ventilation of the apartment wherein the radiator is aced. The radiators are similar to direct radiators in ineral outward appearance, but are provided with a base sting to confine the air and cause it to ascend through the aces of flues between the sections. The radiator stands posed in the room and therefore also serves as a direct diator by emitting the heat from its exposed surface by diation, while the air passing through the flues is warmed r convection. When the air from outside is shut off, rious impairment of the efficiency of the radiator is prented by providing an additional damper in the base, and nnecting it to the other damper, so that in closing one e other is opened, thereby allowing air from the room to culate through the radiator flues. The duct from the base the radiator through the wall is usually made of galvaned iron, fitted with a screen to exclude insects and prevent rds from building nests in the duct, and set at an incline, provided with louvers, to prevent the rain from beating in. he duct usually measures 5½ inches by 17 inches. Two more can be used, if necessary, to supply the required nount of air. Inlets of this type should not be used where is required to change the air of the room more than four mes per hour. One disadvantage presented by semidirect eating systems is the fact that no satisfactory method has et been devised for automatically regulating the flow of ir over the heating surface under differing outside wind ressures. The wind pressure on the side of a building nay range from a light summer breeze to a gale, and thereore the opening designed for a gentle breeze would be too arge for the gale, and with the latter the cooling might take lace so rapidly as to freeze the condensation in the bottom f the radiator. With satisfactory automatic regulating

dampers, the semidirect method of heating would be more generally used. The emission of heat per square foot is greater in these radiators, and hence the boiler capacity must be greater than for an equal amount of direct radiation.

STEAM PIPING

37. The piping for indirect steam heating, or for the semidirect method, must be designed on the same principles as for direct heating. The pipes, however, must be made somewhat larger, because the radiators emit more heat and condense more steam per square foot of surface, and hence, satisfactory drainage is of the utmost importance. The apparatus may be operated with steam of high or low pressure, with exhaust steam, or by the vacuum system, as may be most convenient in each particular case.

The system of piping commonly employed for indirect heating follows the ordinary type of two-pipe work, as shown in Fig. 22. For example, Fig. 27 shows three stacks *a, b, c* of indirect radiators suspended from the cellar ceiling, the main steam pipe *d* rising from the boiler *e* and offsetting to allow for expansion. The branch pipes to the stacks are taken from the top of the main pipe, as shown, and are provided with valves to shut off the supply of steam when heat is not required, or when repairs to the radiators in the casings are necessary. The main shown is of one size throughout its entire length, being dripped at the end through the drip pipe *f*, which relieves the steam-supply main of condensation. The main return *g* is carried along the side wall, draining toward the boiler. Return pipes from the indirect stacks pass out through the side of the casing. The return pipes are then carried back to the wall and drop into the main return. Valves corresponding to those on the steam connections are placed in the return branches. The valves in the return connections may be of the gate, globe, or horizontal swing check pattern. If swing check-valves are used, the attendant has but one valve to close in order to shut off the stack. Check-valves of the horizontal swing

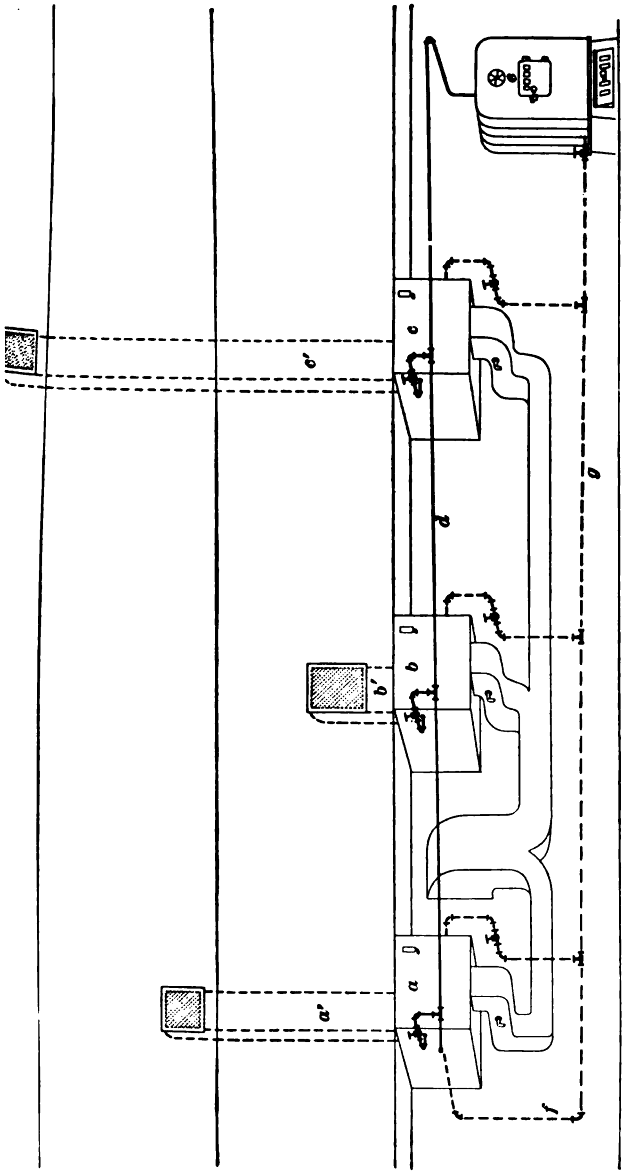


FIG. 27

pattern are used because they will drain. The water backed up by the bridge wall of the ordinary lift check-valve may interfere with the drainage, and if such check-valves are placed in exposed positions, the water in the pipe is liable to be frozen. The main steam pipe could be reduced after passing the first and second stacks, but in that case drip pipes would have to be placed near the connection to each stack, in order to drain the condensation from the steam-supply main to the main return. Any number of stacks may be erected and connected, the mains branching as required, but the drips and connections would be the same. Air valves are attached to the indirect radiators by means of a short pipe passing through the casing and connected into the return end of the stack, having their discharge outlet above the top of the stack, the air valves being placed where they can easily be reached.

38. Fig. 27 shows a separate flue, as a', b', c', passing up in the wall from each stack; this method insures a positive supply of heated air to the room to be warmed. Two different floor connections should not be taken from the one stack or pipe, as the one at the highest elevation will interfere with the delivery of the other. Each flue terminates in an enlarged opening, into which is placed a register. The flues at the back of the registers should be made with a rounding top so that the air in passing to the register will be deflected to the grille or register face. The stack casing should be made so as to allow a proper space above the radiator for the air to escape into the flue, and in no case should this space be less than 8 inches. Below the stack of radiators there should be a similar 8-inch space, so that the air will flow properly through the openings between the sections. The cold air from outside should be brought to the casing of the stack by ducts made of galvanized iron, and the connection to the casing should be as near the end opposite the outlet to the flue as possible, in order to make the distance traveled by the air as great as possible, thus bringing it in contact with the greatest

possible amount of surface and thereby causing it to become more quickly warmed. The air supply for indirect stacks should be brought from the side of the house against which the prevailing winds blow in the winter time, and, if possible, the ducts to the stacks should come from one opening. This insures the air supply against back drafts. If one connection were brought from the north side of the house to a stack supplying a room on that side, and another were brought from the east or south to a stack supplying an adjacent room, the room to the east or south would probably deliver heated air outdoors through the cold-air duct when the wind was blowing from the north.

Each of the connections to the casings should be provided with a damper near the stack, so that the volume of air can be controlled. The main inlet should also be fitted with a damper, so that the velocity of the air entering the room may be controlled as the force of the wind changes. The inlet should have a fine- and a coarse-wire screen to protect the opening from insects, leaves, etc. Settling chambers of large area should also be provided, where possible, so that dirt and dust blown in by the wind may settle before the air enters the fresh-air ducts. In these chambers filtering screens may be arranged to catch the dust on closely woven fabrics, such as cheese cloth, wet bagging, wire gauze, or by charcoal moistened with water.

AIR-VENT PIPING

39. The use of air vents on radiators and coils is necessary in order to provide for the removal of air that would otherwise prevent the steam from flowing freely to the radiator section or other point where the air has accumulated. In the best modern practice, the air and vapor discharged from air vents are removed by a separate system of piping connected to all the air vents.

Small pipes are used for the air lines, which follow the run of the steam pipes and discharge at some point remote from occupied rooms. The air pipes must be as carefully graded

as the steam and return pipes, for water due to the condensation of watery vapor would accumulate in depressions in the pipe and prevent the discharge of the air. This important point is sometimes overlooked in erecting air piping, and the faulty operation of the plant is attributed to imperfect air valves or to some defect in some other part of the system. The size of the piping used should be increased as the number of valves connected up increases. It is customary to make the rising pipes $\frac{1}{2}$ inch in diameter, and the mains in the cellar $\frac{3}{4}$ inch and 1 inch. For horizontal runs the 1-inch pipe can be used with better results, as the pipe can be kept straight, whereas the small pipes are seldom free from twists and depressions.

EXHAUST AND VACUUM SYSTEMS

DESIGN AND INSTALLATION

EXHAUST STEAM-HEATING SYSTEMS

GENERAL DESCRIPTION

1. Economy.—The **exhaust system** of steam heating is in every respect a low-pressure system, except that it is provided with special apparatus that adapts it to receive the exhaust steam from engines and pumps. It is used only for the purpose of saving and utilizing the heat in exhaust steam that would otherwise go to waste. The magnitude of this waste may easily be seen when it is considered that exhaust steam at atmospheric pressure contains 966 British thermal units per pound that are available for heating. The practice of allowing exhaust steam to escape into the atmosphere when it can be used in heating apparatus, either for house warming or heating liquids, etc., is therefore inexcusably wasteful.

To secure an adequate supply of exhaust steam for heating by placing a back pressure of 2 pounds per square inch on an engine operating with a mean effective pressure of, say, 50 pounds, will increase the coal consumption less than 1 per cent.; whereas, for an equal amount of heating by means of live steam, the exhaust steam being discharged into the atmosphere, the coal consumption will probably be increased fully 60 per cent.

The amount of radiating surface that may effectively be supplied with exhaust steam by an engine of given size is estimated by allowing about 4 square feet of radiation to each pound of steam exhausted per hour. In other words, assuming that an engine developing 150 horsepower will have available for exhaust heating 20 pounds of steam at atmospheric pressure, per horsepower per hour, the amount of radiating surface that may be supplied with exhaust steam from such an engine will be $150 \times 20 \times 4 = 12{,}000$ square feet.

The available amount of exhaust steam necessarily varies with the work done by the engine, whose governor is adjusted so that a sufficient weight of steam will be admitted to preserve uniformity of speed under a variable load, only a small weight of steam being admitted if the work is light, and vice versa.

2. **General Arrangement.**—The general arrangement of apparatus for controlling the steam supply and drainage in an exhaust steam-heating system is shown in Fig. 1. The steam-heating main *a* is connected to the exhaust pipe *b* and also to a pipe *c* that supplies live steam from the boilers. When live steam is used it passes through a pressure-reducing valve *e* and is lowered in pressure to the desired amount before entering the heating main. By this arrangement the heating system will be supplied with exhaust steam as long as the engines are in operation, but if for any reason the supply becomes insufficient to maintain the proper pressure, live steam will enter through the reducing valve and make up the deficiency. If the supply of exhaust steam becomes excessive, so that the pressure rises unduly, the excess of steam will escape by opening the back-pressure valve *f* and blowing into the atmosphere. When the engines are stopped the steam in the heating apparatus is prevented from passing backwards and filling them with water by means of the check-valve *g*. This valve is similar to the valve *f* in construction and is so nearly balanced by its counterweight that it will open very easily. The relief valve *f* is usually adjusted to blow off at a

essure about 1 pound higher than that maintained by the ducing valve *e*. The exhaust steam is passed through a parator *d* before entering the heating system, for the purse of removing the entrained water, and especially for moving the oil that accompanies it from the engine.

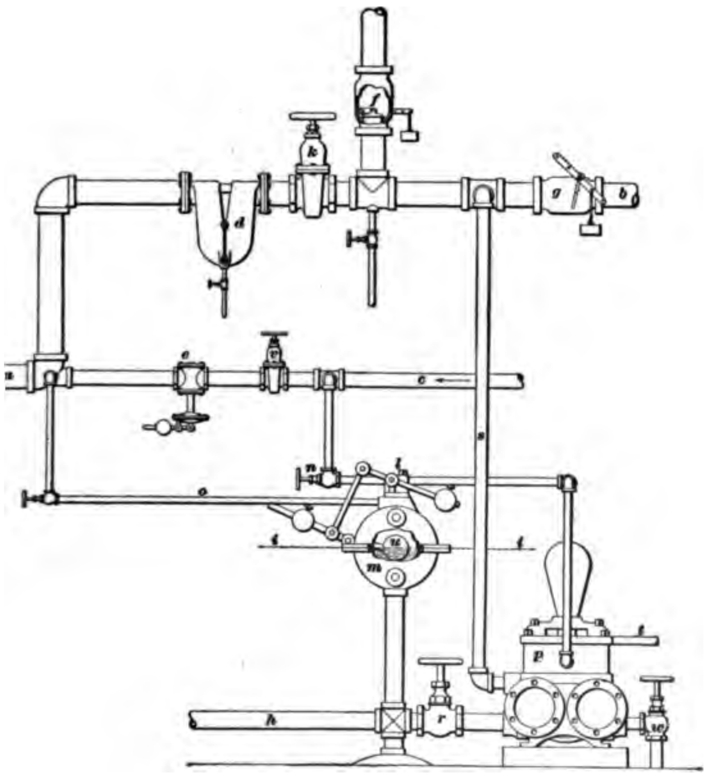


FIG. 1

The drainage from the heating apparatus is collected in e pipe *h* and is returned to the boiler by means of a pump *p*, shown. The returns have no direct connection with the iiler, consequently the water level in them may be mainined at any convenient height, as at *i i*. This is accomished by means of the pump and its governor *m*. The imp governor is merely a closed vessel containing a float *u*

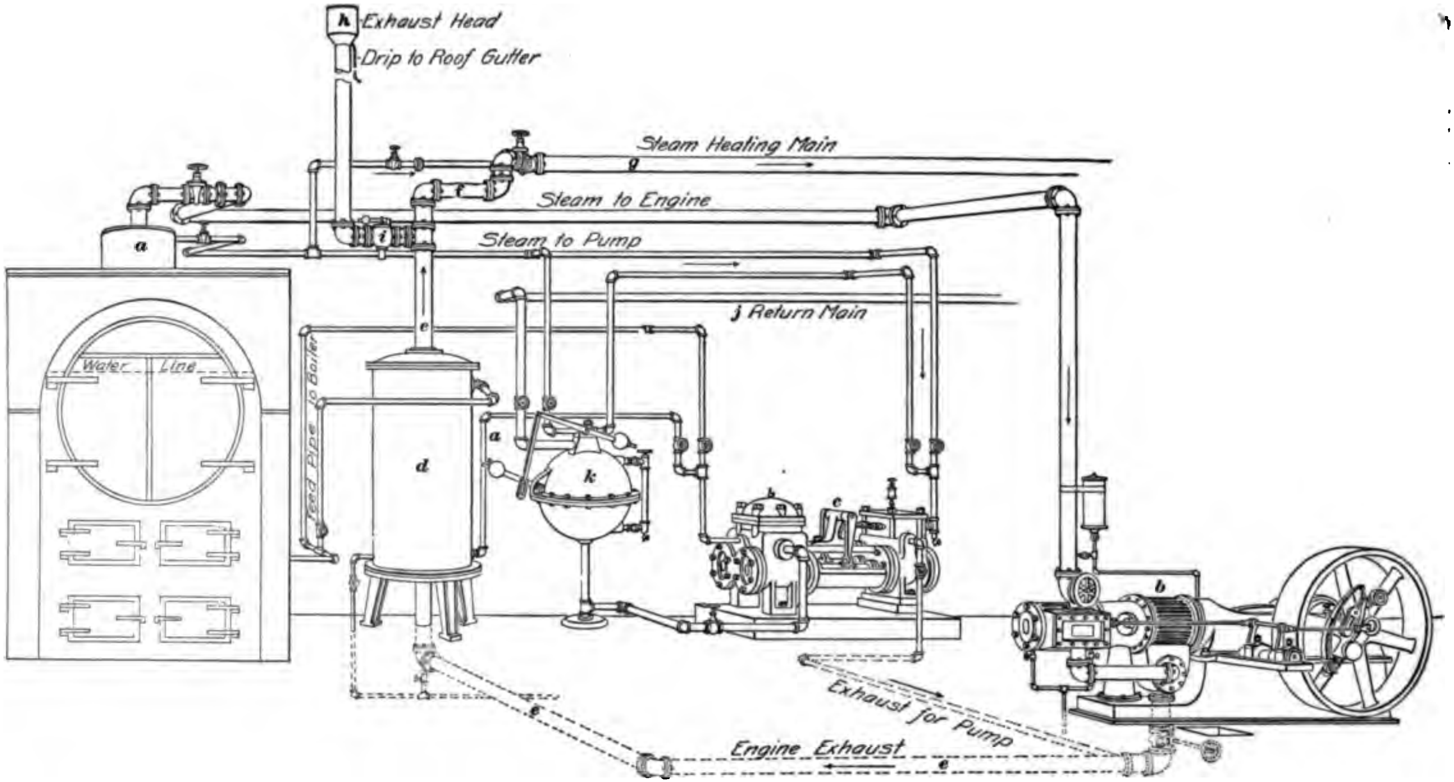
that rises and falls with the water level. The steam that drives the pump is taken from the high-pressure pipe *c* through the stop-valve *n* and passes through a throttle valve *l* that is controlled by the float. When the water rises above the desired level the float opens the throttle and starts the pump; when it subsides the float is lowered and shuts off the steam. The exhaust from the pump is turned into the exhaust main through the pipe *s*. The pump governor is connected to the heating main *a* by a small pipe *o* for the purpose of equalizing the pressure on top of the water therein.

Valves are provided in the main pipes, at *k* and *v*, for the purpose of shutting off the heating apparatus during the summer season. It will be noticed that these valves are so located that they do not interfere with the supply of steam to the pump nor with the exhaust therefrom. The returns are shut off from the pump by the valve *r*, and an independent water supply is attached at *w*. The pump delivers through the pipe *t* to the boiler.

Care must be taken to locate the valves *f* and *g* in proper relation to each other, as shown. If the check-valve is placed between the heating main *a* and the valve *f*, and the reducing valve *e* should get out of order, the pressure would rise in the heating system until it equaled that in the boiler. This increased pressure might burst the radiators and do serious damage. The safety of the whole apparatus depends on the good working condition of the relief valve *f*.

DETAILS OF INSTALLATION

3. Connections to Apparatus.—With the exhaust steam-heating system apparatus arranged as indicated in Fig. 2, the steam-supply connections to the dome of the boiler *a* are so made as to allow for expansion. Separate pipe lines are run to supply the engine *b* and pump *c*, the exhaust steam from both being discharged into the feedwater heater *d*, from which the exhaust pipe *e* rises to a point at which a branch *f* therefrom is connected to the heating main *g*.



Exhaust Head
Drip to Roof Gutter
Steam Heating Main
Steam to Engine
Steam to Pump
j Return Main
Water Line
Feed Pipe to Boiler
Exhaust for Pump
Engine Exhaust

FIG. 2

The exhaust main is carried upwards to any convenient height above the roof, where it is provided with an exhaust head *h*, as shown. The valves on the supply and return risers being open, steam passes through the heating apparatus, and any excess of steam escapes into the atmosphere through the back-pressure valve *i*. The pump *c* forces the cold feedwater through the coils in the feedwater heater, and thence to the boiler. The main return pipe *j* is connected to the pump governor *k*, which in turn is connected to the suction of the pump *c*, so that the water of condensation from the heating system may be utilized for feedwater, thereby lessening the amount of fuel that must be burned.

4. **Separation of Oil and Grease From Feedwater.** Before exhaust steam is used for heating purposes, provision should be made for the removal of the lubricating oil and grease, which would otherwise greatly reduce the heat-emitting efficiency of the radiators. Furthermore, the decomposition of greasy organic matter will produce gases having an offensive odor that would be very disagreeable if the air valves discharged into the rooms heated. The removal of oil and grease may be accomplished, as indicated in Fig. 3, by discharging the exhaust steam into a large tank *a* in which the water and grease separate by gravity from the steam and fall to the bottom of the tank. The grease is drawn off through a siphon *b* in the tank and discharged into the sewer, or into some receptacle where it is filtered. The supply pipes *c*, *c* to the various radiators are shown as being taken separately from the tank, but they might also be taken from the tank as shown at *c'*. The water of condensation from the heating system returns through separate pipes *d*, *d* to a manifold *e* by which connection is made to a return tank *f*. A live-steam connection *g* from the boiler to the separating tank is provided for supplying steam to the heating system in case the engine should be shut down for repairs, as well as to admit additional steam when the amount of exhaust is insufficient. A draw-off pipe *h* is provided for draining the return tank *f*. The pipe *i* is provided for equalizing the

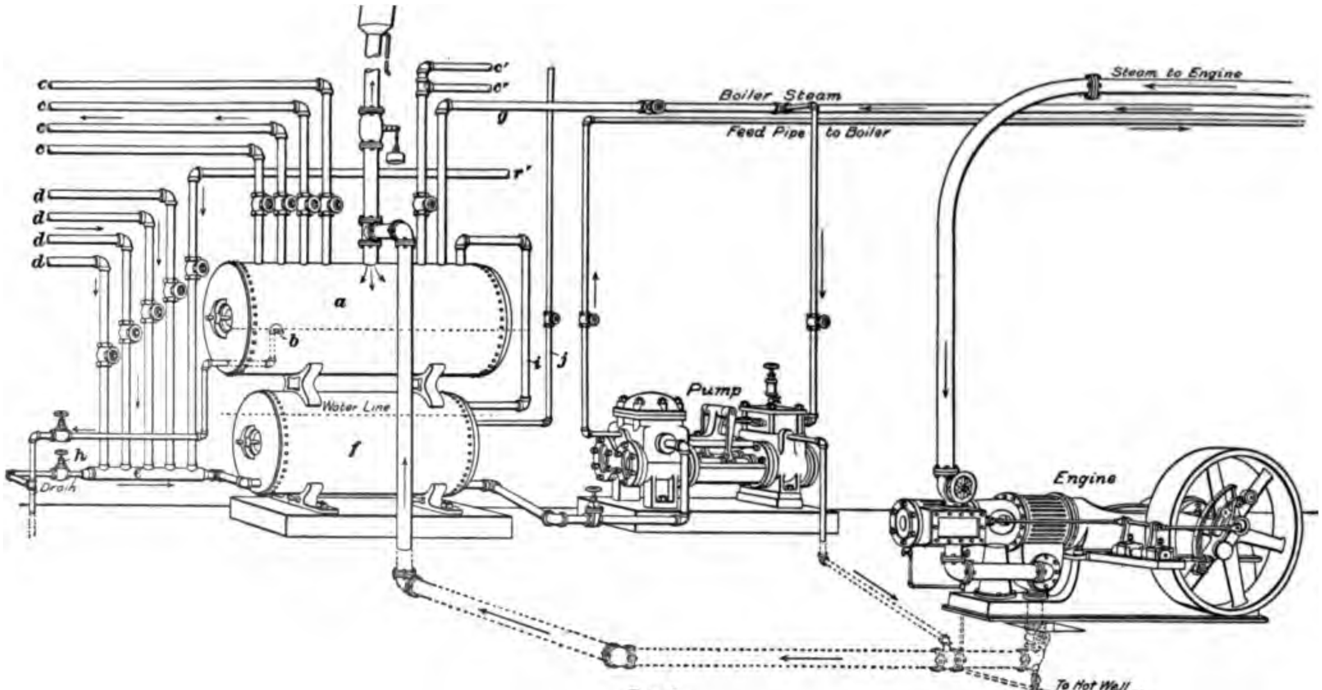
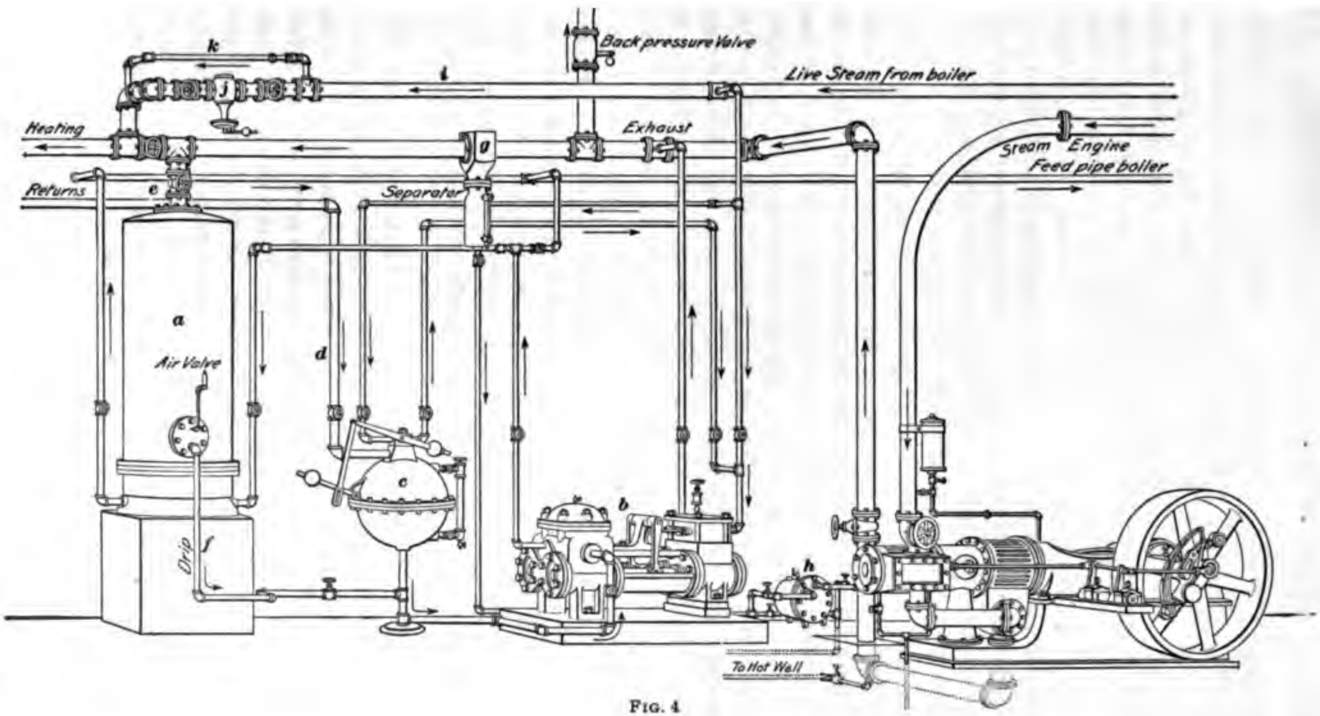

Steam to Engine
Boiler Steam
Feed Pipe to Boiler
c
c
c
c
c'
c"
g
r'
d
d
d
d
a
b
i
j
Water Line
f
h
Drain
Pump
Engine
To Hot Well

FIG. 3

pressure in the steam tank and water tank, thereby forming a gravity heating system, with a water-line in the return tank *f* sufficiently high to seal the valves of the pump. A cold-water pipe *j* is provided in order that cold water may be used to make up any waste of the water required to maintain the feed-supply to the boiler. In operation, steam flows from the tank through the piping under a slight pressure, the water of condensation flowing through the return pipes to the return tank, to which the suction of the pump is connected, and by the latter the water is forced into the boiler.

5. Details of Steam Piping and Feed-Piping.—The arrangement of apparatus shown in Fig. 4 is intended to provide for as nearly an automatic operation as it is possible to obtain. The direction of the flow of live and exhaust steam is indicated by the arrows. The feedwater heater *a* is of the closed type, the pump *b* forcing the water to the boiler through the heater. The water of condensation returns to the top of the receiver of the pump governor *c*, to which the return pipe *d* drops as a dry return. The return might also be connected to the bottom of the receiver, and thereby sealed, as in Fig. 5, in which case a balance, or pressure-equalizing, pipe, as *e*, Fig. 5, would have to be placed between the steam heating main and the top of the receiver. With a dry return, a balance, or pressure-equalizing, pipe connection with the heating main is not necessary, the water of condensation entering the receiver of the pump governor at a point above the water-line maintained therein, so that the pressure in the return is necessarily the same as that in the receiver. The steam-pipe connection between the pump and the receiver of the pump governor is arranged so that the pump may be run independently of the operation of the pump governor, the necessary valves being placed in the connections to permit the use of either method. The piping of the feedwater heater is also supplied with valves, so that in case the feedwater heater gets out of order the water may be pumped directly to the boiler without passing through the feedwater heater. The exhaust-steam connection *e* to the



k
Back pressure Valve
i
j
Live Steam from boiler
Heating
g
Exhaust
Steam Engine
Feed pipe boiler
Returns
e
Separator
a
Air Valve
d
c
b
h
Drip
f
To Hot Well

FIG. 4

heater, into which the steam is deflected, is made with but one valve. The water of condensation from the feedwater heater gravitates through the drip pipe *f* to the pump governor. As the exhaust pipe is fitted with a grease extractor *g*, which clears the oil from the steam before passing to the heater or heating apparatus, the water of condensation therefrom can be used for feeding the boiler. If the water of condensation from the heating apparatus is not sufficient to supply the boiler, the additional make-up water required may be secured through a cold-water pipe connection. When the heating apparatus is shut off the cold-water supply pipe may be connected to the pump governor or to the pump direct. When connected to the pump governor the supply is readily regulated according to the requirements of the boiler, the pump injecting the supply periodically as the water accumulates. The waste oil from the grease extractor *g* is piped to a steam trap *h* and discharged to the sewer, or saved for further use by filtering. As a rule, the oil is heavy and thick, so that it is necessary to arrange a steam pipe in the filter to keep the oil hot, as the filtering process is slow. In small plants the cost of oil is too low to lose time in filtering it, and hence the oil is usually wasted. The live-steam connection *i* from the boiler to the heating system is provided with a reducing valve *j*, around which a properly valved by-pass *k* is arranged, so that the apparatus need not be shut down while necessary repairs are being made.

6. The method of making the balance-pipe and other connections to the pump governor *a* is illustrated in Fig. 5. The supply of cold make-up water is regulated by hand, but it is evident that by using another pump governor and attaching it to the cold-water supply pipe *b*, any deficiency in the make-up water could be supplied by the automatic operation of the pump *c*, which would maintain a uniform water-line in the boiler under all conditions. To accomplish this object it would be necessary to place the additional pump governor with the center of its receiving chamber at the proper water-line and to attach it to the steam and water spaces of the

n the same manner as is ordinarily followed in attach- 'ater column. The cold-water pipe for the additional ;overnor should be connected to the automatic valve *d* ›ed so that it will discharge a sufficient quantity of into the pump-governor receiver *a* to maintain a

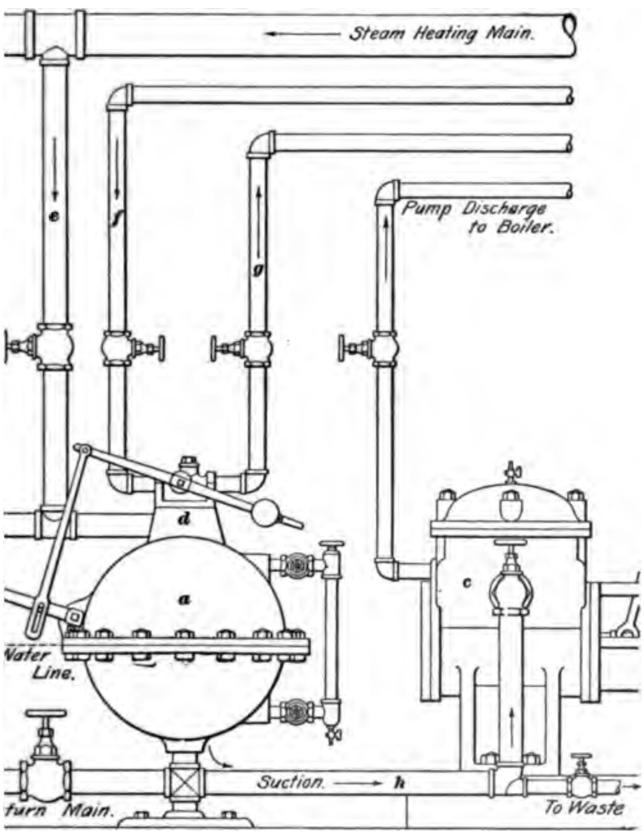


FIG. 5

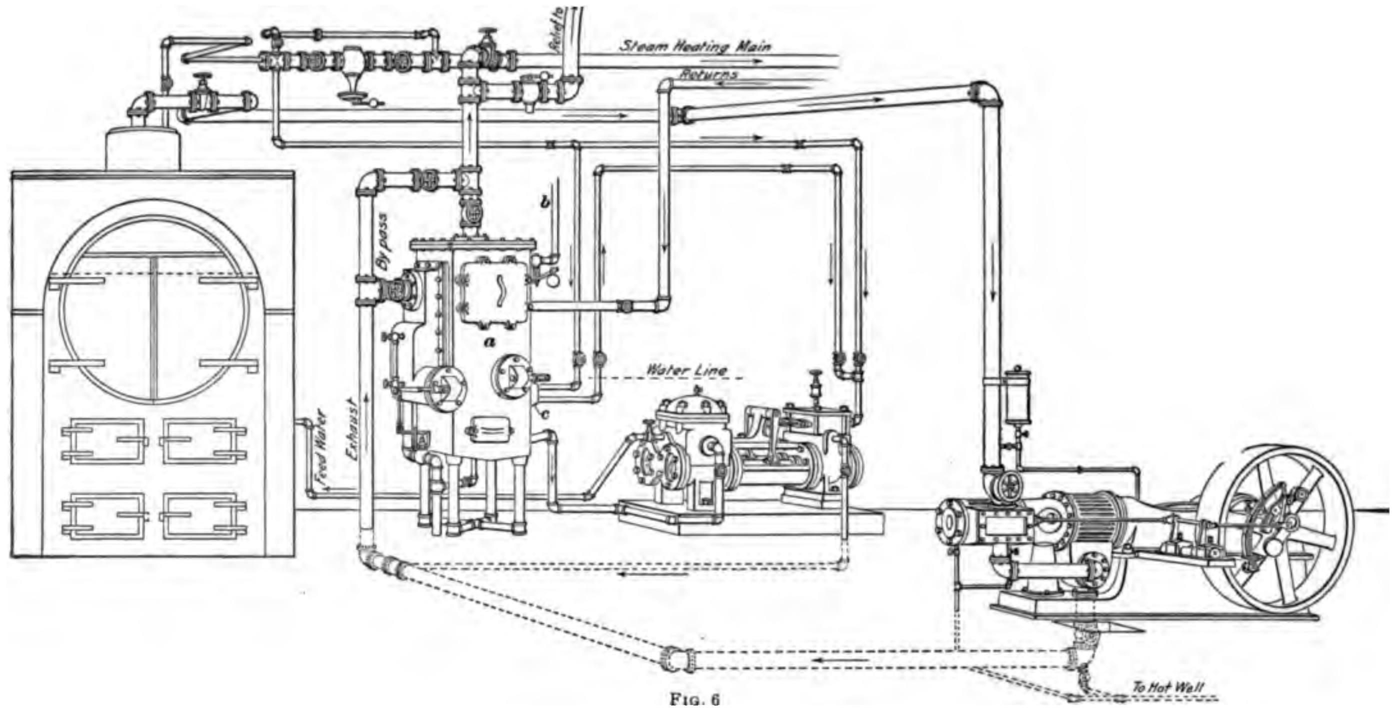
ı water level in the boiler, thereby providing against explosion. When used in connection with a battery ers each boiler might be provided with a similar or, the valve at the boiler being arranged to admit dwater by connecting the automatic valve *d* to the

feedpipe direct. Then the water-line in each boiler would not be dependent on the personal care of the fireman but would be maintained automatically.

When connected up as shown in Fig. 5 it is necessary to close the valve in the balance pipe *e* between the heating main and the chamber of the pump governor whenever a supply of make-up water is required, the valve *e* being opened again after the valve in the cold-water supply pipe *b* is closed. The supply of steam from the boiler to the pump *c* through the pipes *f* and *g* is controlled by the automatic valve *d*, the pump being started when the water of condensation returning from the heating system through the pipe *h* raises the float within the pump-governor chamber and thereby opens the valve through which steam is periodically and automatically supplied to the pump. The suction pipe *k* of the latter is connected to the pump governor, as shown.

All automatic devices should be provided with valves and suitable by-pass connections, so that in the event of a breakdown or stoppage in any pipe, direct connections may be used while repairs are being made.

7. When the open type of feedwater heater, that is, the type in which the exhaust steam and water are in contact, is used with exhaust steam-heating systems, as shown in Fig. 6, the piping is substantially the same as previously shown, the direction of the flow of exhaust and live steam being indicated by the arrows. The exhaust steam from the engine and pump enters the side of the feedwater heater *a* at a point just above the limit set for the water level in the body of the heater and passes through a grease extractor, consisting of a series of fluted baffle plates on which the grease and water collect, falling by gravity into a chamber below. The steam then enters the body of the heater and passes upwards to the escape pipe. In the space above the exhaust inlet are several trays that cause the steam to take a zigzag course, passing under and over them to the escape pipe at the top. To the top tray a water pipe *b* is connected to supply the

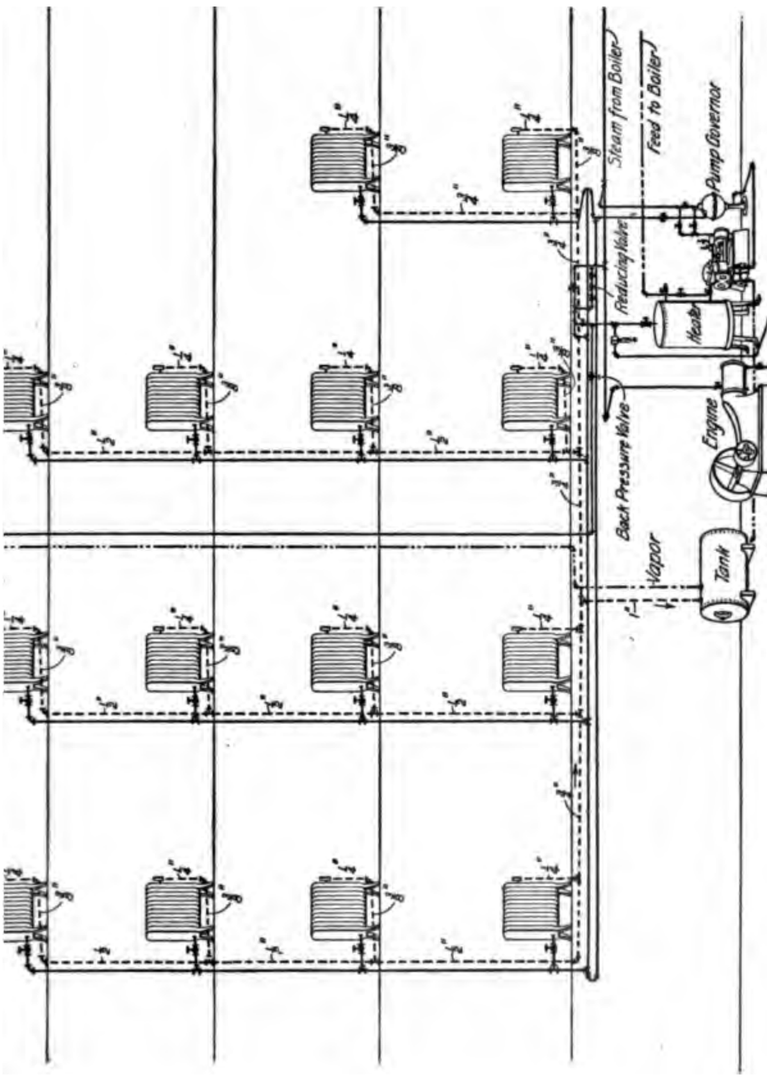


Relief to
Steam Heating Main
Returns
b
By pass
a
Water Line
c
Exhaust
Feed Water
To Hot Well

Fig. 6

make-up water. The water flows through channels in the tray, so that it is distributed over the full area thereof, overflowing to the tray beneath, and thence to the other trays until, heated to the temperature of the steam, it falls into the body or receiving chamber beneath. The escape pipe has a branch to the heating main, with a valve to shut it off when the heating apparatus is not required. The water of condensation from the heating system is brought back to the feedwater heater below the water-line therein. The water for feeding the boiler is drawn from the heater at about 210° and is pumped directly to the boiler.

The apparatus shown in Fig. 6 represents a gravity-return system, with the water-line in the feedwater heater, independent of that in the boiler, at a sufficient elevation to seal the valves of the pump. The system is balanced by the connection of the exhaust pipe to the top of the heater, the latter being provided with an overflow pipe, not shown, to permit the water of condensation, in case it is returned intermittently in a flood, to overflow to the sewer through a steam trap and thus relieve the heater before the water can rise to the level of the inlet of the exhaust pipe. Some feedwater heaters are fitted with a filtering attachment, so that the impurities in the water are removed. As shown, the exhaust pipe is connected to the heater with a by-pass, so arranged that the heater may be used independently of the exhaust from the engine when the latter is shut down, or when repairs to the heater are necessary it may be cut out of service entirely. For feeding the boilers an additional pump should be connected to the cold-water pipe and cross-connected to the feedwater heater. This pump can be used for other purposes, such as filling the house tank, as is required in many plants where power is used. The automatic attachment for controlling the supply of steam to the pump is placed in the body of the heater, and consists of a ball float that operates a balanced valve in the projection at outside the body of the heater. The steam pipe to the engine is carried directly from the boiler to the engine, and a separate pipe is used for the pump and the heating supply.



Steam from Boiler
Feed to Boiler
Pump Governor
Reducing Valve
Heater
Engine
Back Pressure Valve
Vapor
Tank

FIG. 7

With this method of piping, a break in the engine piping would not affect the operation of the pump or the heating system.

8. Air Piping.—Air discharged from radiators is often charged with foul-smelling gas due to impure water, and if discharged into the rooms is disagreeble; therefore, air valves should be connected to pipes leading to some place away from the building, where the air may be discharged without causing discomfort. The air pipes may be connected to a leader or other escape pipe to the roof. The method usually followed in connecting these pipes to radiators is shown by the dotted lines in Fig. 7, which also indicates the sizes of air lines commonly employed. The radiators are shown as being connected up on the single-pipe system, the air valve being attached to the return end of the radiator. The air pipes should be run with the same care as the steam and return pipes and gathered together in the cellar or basement, where, as shown, they discharge into a tank from which a breathing, or vapor, pipe is carried upwards through the building to a point above the roof. When the tank is full of condensation water, the engineer can open the valve and pump it back to the boiler.

9. Combination High-and-Low Pressure Systems. The system illustrated in Fig. 8 is one that may be used at any pressure above that of the atmosphere. The main return pipe *a* leads to a hotwell or return tank *b* having a pipe *c* open to the atmosphere. Each radiator is fitted with an expansion trap, as *d*, at the return end, to prevent the direct passage of steam at a high pressure to the atmosphere. Exhaust steam may be used, provided that the grease is eliminated from it before passing to the radiators, as the opening in the expansion trap on the radiator return connection is small and grease will clog it. Boiler steam at any pressure above that of the atmosphere may be used, and as the radiator condenses the steam, the water of condensation passes to the trap *d* at the return end. If the steam should flow through the trap, the resulting expansion will close the trap and thereby check the waste of steam. When the

ndensation has cooled the trap sufficiently, the trap valve ens and the water flows into the open return pipe *a* rough which the air from the radiator and vapor from the ater of condensation escape to the roof. If but a portion

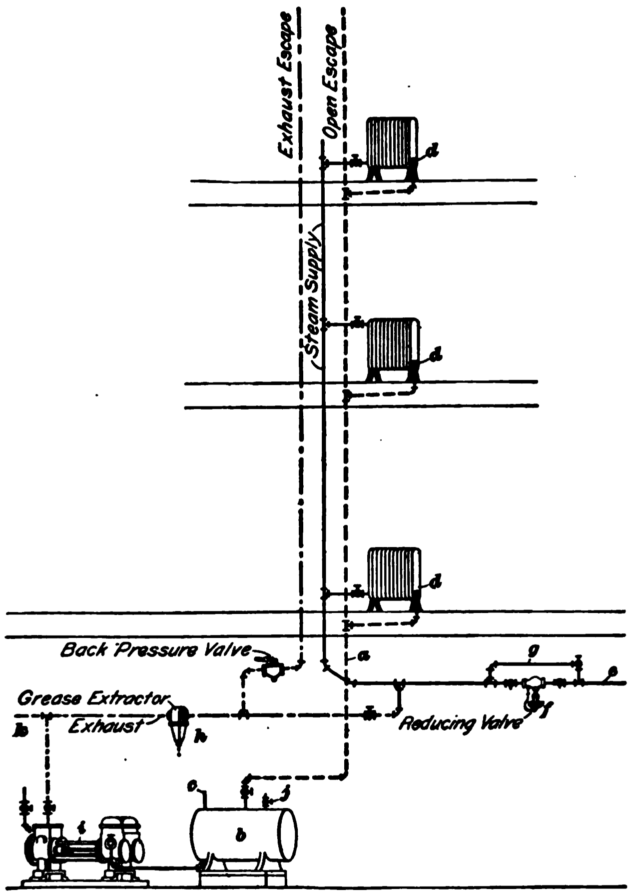


FIG. 8

the radiator is to be warmed, the valve on the steam pipe ay be opened slightly, and by adjusting the valve to the quirements of the occupant, the temperature of the room ay be regulated. The pipe *e* from the boiler is provided

with a reducing valve *f* and by-pass *g*, so that exhaust or live steam may be used. The grease is extracted by means of a separator *h* and discharged through a trap, not shown. The clean condensation water drains back to the return tank *b*, from which a pump *i* returns it to the boiler. A cold-water pipe *j* may be connected to the tank for supplying additional water for the boiler, in case the amount of condensation is not sufficient. The system is operated and adjusted by hand, but can be arranged to operate automatically.

10. The traps for the return pipes in the system illustrated in Fig. 9 are made in the form of siphons by carrying the return branches *a*, *a* from the radiators downwards a distance of 10 or 12 feet before making the connection to the return riser *b*, a check-valve *c* being used, as shown, to prevent the steam pressure in the return pipe from forcing water back to the radiator in case the pressure in the radiator should fall below that in the return pipe. It is evident that the limit of difference of pressure or drop throughout the system is given by the distance between the return connection to the first-floor radiator and the bottom of the return tank *d*. With a gravity-return feedwater system, the receiver would have to be placed as high above the boiler as the pressure therein would maintain the column of water in the receiver without flooding the return pipe, which should be above the receiver in order to discharge into it. In the system shown in Fig. 9, however, the water of condensation is pumped back to the boiler, and hence the pressure drop may be greater than with a gravity boiler feed. Steam may be taken directly from the boiler through *e* or from the exhaust main. In each radiator connection to the steam riser *g* is inserted a valve by which a small or a large amount of steam may be admitted to the radiator, as the occupant of the room may desire. The steam condenses, and if there is no back pressure in the return riser, the water of condensation will flow down the return pipe and through the check-valve; and if there is any back pressure, the water will accumulate in the return pipe above the check-valve until its weight

overbalances the pressure, when it will flow into the return riser. The return riser must be open to the atmosphere if it is desired to operate without back pressure; whereas, when a back pressure is desired, an air valve *h* must be placed at

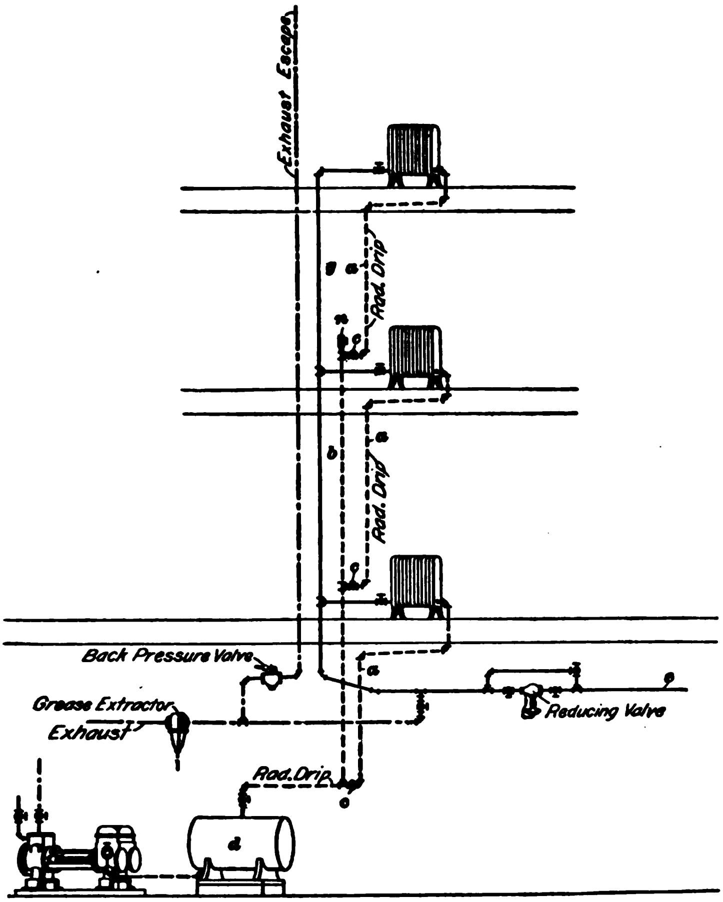


FIG. 9

the top of the pipe, so that the air in the system may be discharged. The steam in the main pipe may be under a pressure equal to that due to the head of water maintained in the radiator return pipes.

11. The illustrations thus far presented show the best methods of utilizing exhaust steam with more or less back pressure on the engine. If proper care is taken in designing such systems, they may be operated with very slight back pressure. Being gravity systems, as a rule, and balanced at all points, there should be an equalization of the distribution of steam, so that each radiator or coil may have an ample supply of steam to fill the radiator completely and thereby to prevent unequal pressures in the pipes leading to the feed-water heater. In order that the radiators may be active at all times, the air valves on the radiators must be sensitive, so that they will respond quickly to the cooling that takes place with the accumulation of air, which loses its heat faster than the steam.

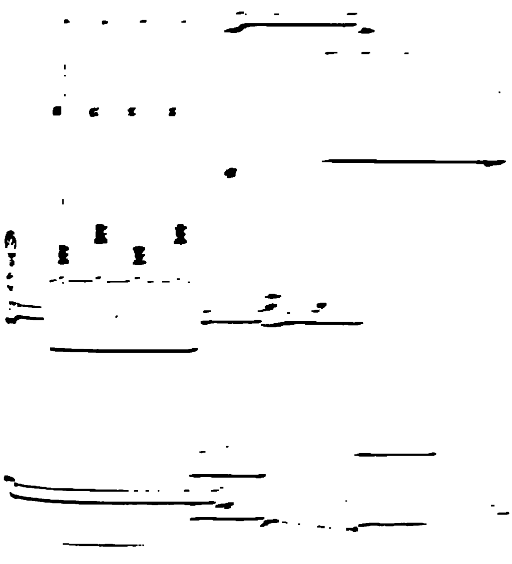
VACUUM STEAM-HEATING SYSTEMS

GENERAL DESCRIPTION

12. Operation.—The **vacuum system** of steam heating differs from all others in one important particular, namely, that a more or less perfect vacuum is constantly maintained in the returns by pumps or other devices. This permits the system to be operated with steam of any convenient pressure, high or low, and from any source, either exhaust or otherwise. The pressure and temperature throughout the whole system may be adjusted and maintained at any degree between full-boiler pressure and a low vacuum, thus making the system adjustable to suit all conditions of weather and service. Strictly speaking, a vacuum system is one that is operated at a pressure less than that of the atmosphere. Generally the system is operated with exhaust steam, the supply being arranged as shown in Fig. 10. The piping is usually arranged on the two-pipe system, and the returns are generally made independent, although it is not necessary to do so in all cases.

Fig. 10 shows the essential features of the system. The returns *a*, *a* are connected to a receiver *b*, in which all the air

[illegible] water in the system [illegible]
[illegible] of the *vacuum* [illegible]
[illegible] condenser [illegible]
any degree desired [illegible]
[illegible] may be used [illegible]
[illegible] operate the [illegible]
[illegible] end of each [illegible]
[illegible] air is [illegible]
[illegible] begins to [illegible]



[illegible]

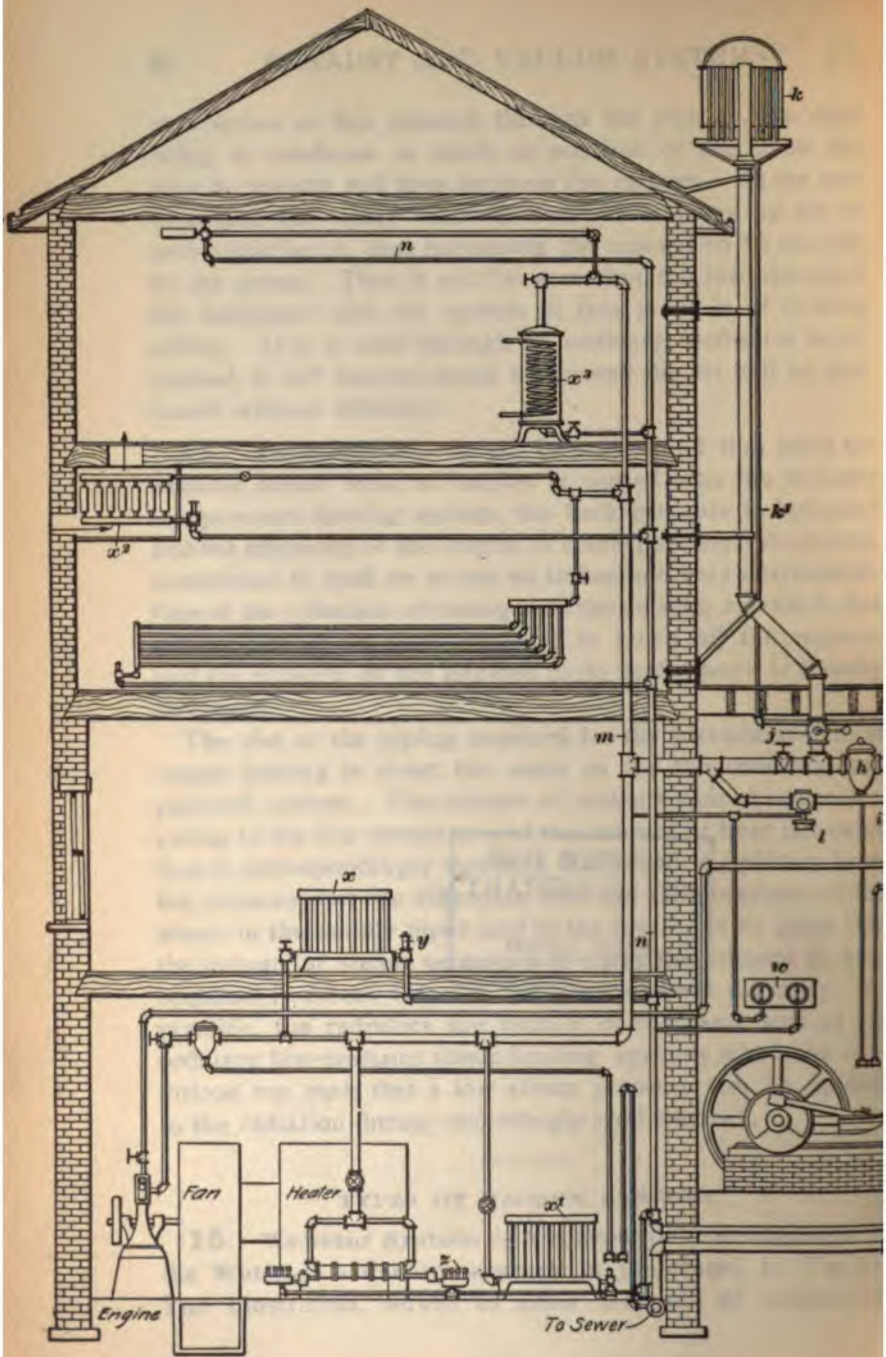
in a series of fine streams through the pipe w, the object being to condense as much as possible of the steam that may be present and thus improve the vacuum. At the same time that the water becomes warmed it gives up the air accompanying it, thus increasing the amount to be removed by the pump. Thus it will be seen that the introduction of the feedwater into the system at this point is of doubtful utility. If it is sent through an ordinary feedwater heater instead, it will become much hotter and the air will be eliminated without difficulty.

14. Advantages.—It will be understood that when the exhaust steam from an engine is turned into the ordinary low-pressure heating system, the back pressure is increased and the efficiency of the engine is correspondingly decreased, sometimes to such an extent as to become very detrimental. One of the principal advantages of the vacuum system is that a great part of the back pressure is taken off the engines, and the capacity of the engines to do useful work is thereby increased.

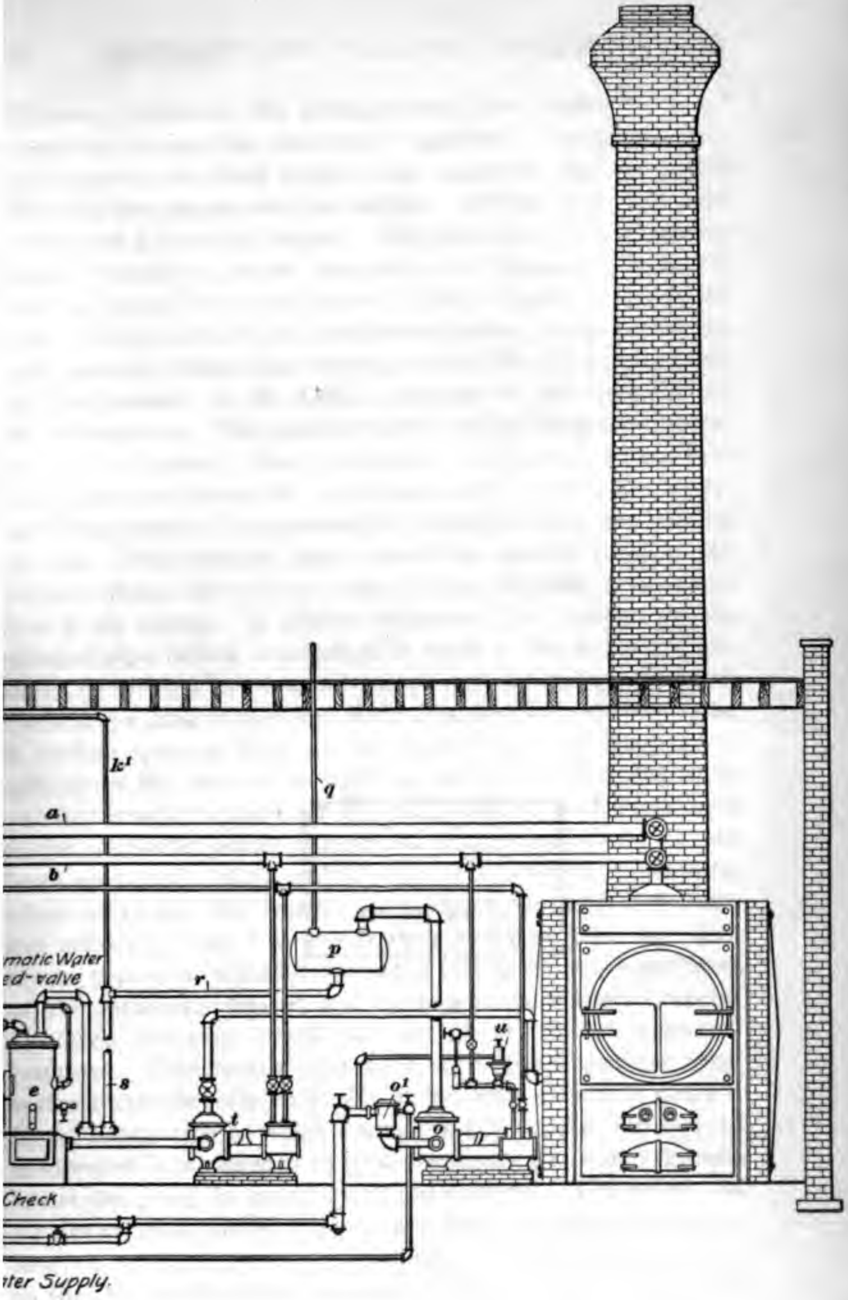
The size of the piping required for the vacuum system of steam heating is about the same as for the ordinary low-pressure system. The volume of steam required is greater, owing to the low pressure, and the amount of heat per cubic foot is correspondingly less than that found in ordinary heating systems, but the difference between the pressures of the steam in the supply pipes and in the returns is so great that the volume of steam necessary to carry the amount of heat required is driven through the pipes without difficulty. In practice, the radiators are usually of the same size as for ordinary low-pressure steam-heating systems when the conditions are such that a low steam pressure can be applied to the radiation during exceedingly cold weather.

TYPES OF VACUUM SYSTEMS

15. Webster System.—A conventional arrangement of the **Webster vacuum system** is illustrated in Fig. 11. The illustration serves to show methods of connecting



k
n
x³
x²
k¹
m
j
h
l
x
y
w
x¹
Fan
Heater
Engine
To Sewer


k¹
q
a₁
b'
p
r₁
matic Water
ed-valve
e
s
t
u
o¹
o
Check
ter Supply

different appliances, the arrangement given being modified in practice to suit the conditions imposed. The pipe *a* supplies steam to the main engine only, while the pipe *b* supplies steam for the pumps and fan engine. A separator *c* is placed in the pipe *a* near the engine. The drip from this separator passes through a steam trap *d* to the feedwater heater *e*. Exhaust steam from engines and pumps passes through the pipes *f* and *g* into a closed feedwater heater connected to the main vacuum return pipe through which the air is extracted, and the pressure in the heater reduced to less than that of the atmosphere. The partial vacuum in the feedwater heater causes the steam to flow freely into the heater, where it is condensed and heats the make-up water required to supplement the water of condensation returned from the heating system. The exhaust pipe *f* from the engine rises to the ceiling, where the exhaust pipe *g* from the pumps connects into it, as shown. A grease extractor *h* is inserted in the exhaust pipe before connection is made to the heating apparatus, to which a live-steam by-pass connection *i* is provided. The escape pipe is provided with a back-pressure valve *j* and is carried upwards from a point near the grease extractor to and above the roof of the building, where it terminates in an exhaust head *k*, from which the condensation is dripped back to the feedwater heater through k^1, the oil and grease having been extracted. Live steam may be employed for heating when necessary, the steam passing from the main *b* through the reducing valve *l* to the heating main or riser *m*. The return pipe *n* is carried downwards to a point below the level of the feedwater heater, and is thus made a sealed return, although the pipe could be carried above the heater if required. This return pipe does not connect with the feedwater heater directly, as in Fig. 6, but with a vacuum pump *o*, in the connection to which a strainer o^1 is placed, and a jet of cold water is introduced to cool the return water and thereby assist the pump in maintaining the vacuum. The water and air drawn from the return pipe are forced by the pump into a receiver *p*, placed at an elevation above the feedwater heater, so that the water in the receiver will flow by gravity into the

feedwater heater. The receiving tank *p* has a vent pipe *q* to the atmosphere through which the air in the system is discharged. In the pipe *r* from the receiver *p* a water trap or loop seal *s* is provided, so that in case of a pressure in the system, the water or the steam in the feedwater heater will not escape should the vacuum pump be stopped. The seal also prevents the atmosphere from rushing into the heater when the pressure in the heater is below that of the atmosphere. The water in the feedwater heater is pumped into the boiler by a feed-pump *t*. The vacuum pump *o* is fitted with an automatic controlling device *u* connected to the steam and vacuum pipes, so that the pump will slow down when the vacuum has reached a certain point and speed up again as the vacuum is lost. The make-up water supply to the feedwater heater is controlled in a manner similar to that described in connection with Fig. 6. The waste drips from the grease extractor *h* and the overflow from the feedwater heater *e* are connected into a pipe *v* that discharges into the sewer. Each drip pipe is connected to this waste pipe by loop seals, so that in case a pressure exists in the system, the seals will not allow steam to escape. If these seals are not capable of preventing the steam from passing through the pipe, it becomes necessary to use a steam trap. When the engine is not running, steam for heating may be supplied through the pipe *b*. Only one valve is shown as being provided to shut off the supply of live steam, but there should be a valve at each side of the reducing valve *l*, around which a by-pass should be arranged, so that the reducing valve could be repaired, if necessary, without shutting down the apparatus. The gauges shown at *w* indicate, respectively, the pressure on the heating main *m* and the vacuum on the return main *n*.

16. The connections to the radiators and other fixtures are somewhat different from those commonly employed with gravity systems. Taking the radiator *x*, for example, the steam-supply radiator connection is provided with an angle valve, but the return pipe has a trap *y* or thermostatic valve, shown in section in Fig. 12, in the connection at the radiator.

In operation, when the radiator is cold the expansion stalk *a*, Fig. 12, in the valve will be contracted, so that when steam is admitted to the radiator the partial vacuum in the return pipe will cause the steam to fill the radiator quickly, the water of condensation falling to the bottom of the radiator and being drained into the return pipe through the passages *b*, *c* and *d*, *d* in the valve-seat bushing *e* that is surrounded by a protecting strainer *f*. The steam, when it comes in contact with the stalk, expands it, and the orifice *c* of the valve is contracted or closed. As the stalk cools again, the orifice is enlarged and the water passes out of the radiator. Adjustment of the stalk is obtained, as indicated, by means of the screw *g* at the top of the valve, Fig. 12.

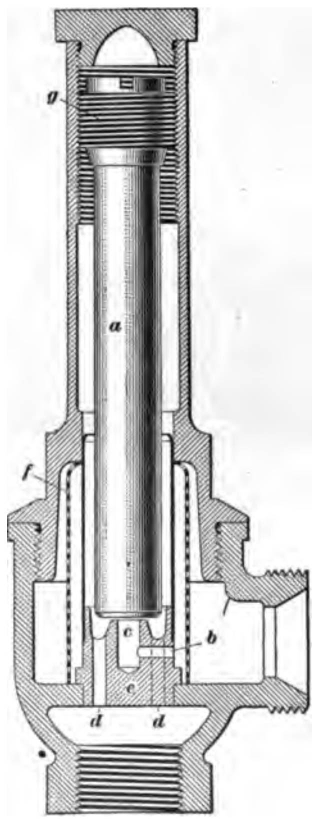


FIG. 12

Before inserting the valve-seat bushing *e*, the radiator should be cleaned of any grease, dirt, or grit that might clog the orifice and thus impair the efficiency of the valve. For this purpose dirt pockets are placed in the connections at *z*, Fig. 11, where a hot-blast heater coil is shown connected to the return below the level of the return pipe at the pump. The heating surface in the coil is greater than one thermostatic valve can control, and hence a multiple thermostatic valve device is used. This valve device represents a combination of several expanding stalks that are inserted in one body, the action being the same as with one stalk, or the first stalk may be heated and closed while others are open, according to the amount of water and temperature.

The radiator x^1, Fig. 11, is below the pump level, and the condensation from it is raised above the top of the radiator to keep it free from condensation. In an ordinary gravity heating job this would be difficult, but with the vacuum system the pressure on the return pipe is considerably less than that in the radiator, and hence the water will be forced up to the level required to discharge it into the pump. This arrangement, however, is not advisable where it can be avoided. In a conventional way, the method of connecting to indirect radiators is shown at x^2, while at x^3 is shown the method of connecting water heaters where steam is used to heat water for domestic use. Old heating systems may be altered to vacuum systems wherein the operating pressure will not exceed that of the atmosphere.

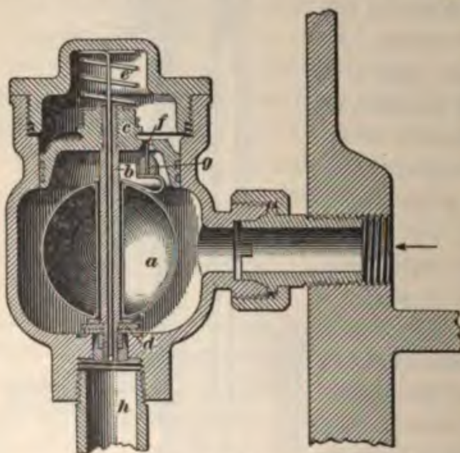


FIG. 13

17. Except for use in connection with small radiators, the thermostatic valve shown in Fig. 12 may be superseded by the motor valve shown in Fig. 13. The latter comprises a float *a* through which extends loosely a hollow stem *b* attached to the piston *c* and carrying a valve disk *d* that is held to its seat by the spring *e*. The operation of the piston *c* depends on the difference between the pressure in the radiator and that in the return line. When the radiator is not condensing steam, the valve disk *d* is held to its seat by the spring *e*, and only a slight escape of air through the stem *b* is possible. When the water of condensation flows into the valve, the float *a* rises until the port *f* is closed by the plug *g*, when the pressure above the piston *c* will become

the same as that in the return pipe, with which the upper chamber is in communication through the hollow stem *b*. The higher pressure of the supply side raises the piston *c* and attached valve disk *d* so as to permit the escape of water of condensation into the return pipe *h*. With the escape of condensation the float *a* descends, opening the port *f* and thereby causing an equalization of the pressure on both sides of the piston *c*; the spring *e* then again seats the valve disk *d* ready for another operation, previous to which any accumulation of air is drawn out of the radiator into the return pipe through the hollow stem *b* by the suction of the vacuum pump to which the return piping is attached.

Before inserting the interior mechanism of the valve it is necessary to see that all burrs, chips, sand, pipe cement, and other dirt is washed out of the radiators and piping system, steam being permitted to blow freely through the apparatus for several days, if possible. After the washing-out process is finished, the inner parts of the valve may be placed in position, care being taken that the valve guide at the end of the hollow stem enters its seat properly. Since the operation of the valve depends solely on the difference in pressure on either side of the piston *c*, no readjustment of the valves is necessary after once being properly set.

18. Paul System.—What is known as the **Paul system** of heating is illustrated in Fig. 14. The general arrangement of the mains in the basement is similar to that of the systems previously described. From the boiler *a* steam is supplied to the engine *b*, from which the exhaust passes to the feedwater heater *c* and thence to the heating system, the feed-pump automatically returning the water of condensation to the boiler from the receiver *d* alongside of the feed-pump. A by-passed reducing valve *e* in the supplementary live-steam connection controls the supply of steam from the boiler in making up for any deficiency in the available amount of exhaust steam. The escape pipe to the roof is provided with a lightly weighted back-pressure valve *f*. The return pipe is connected to an automatic pump governor, as in

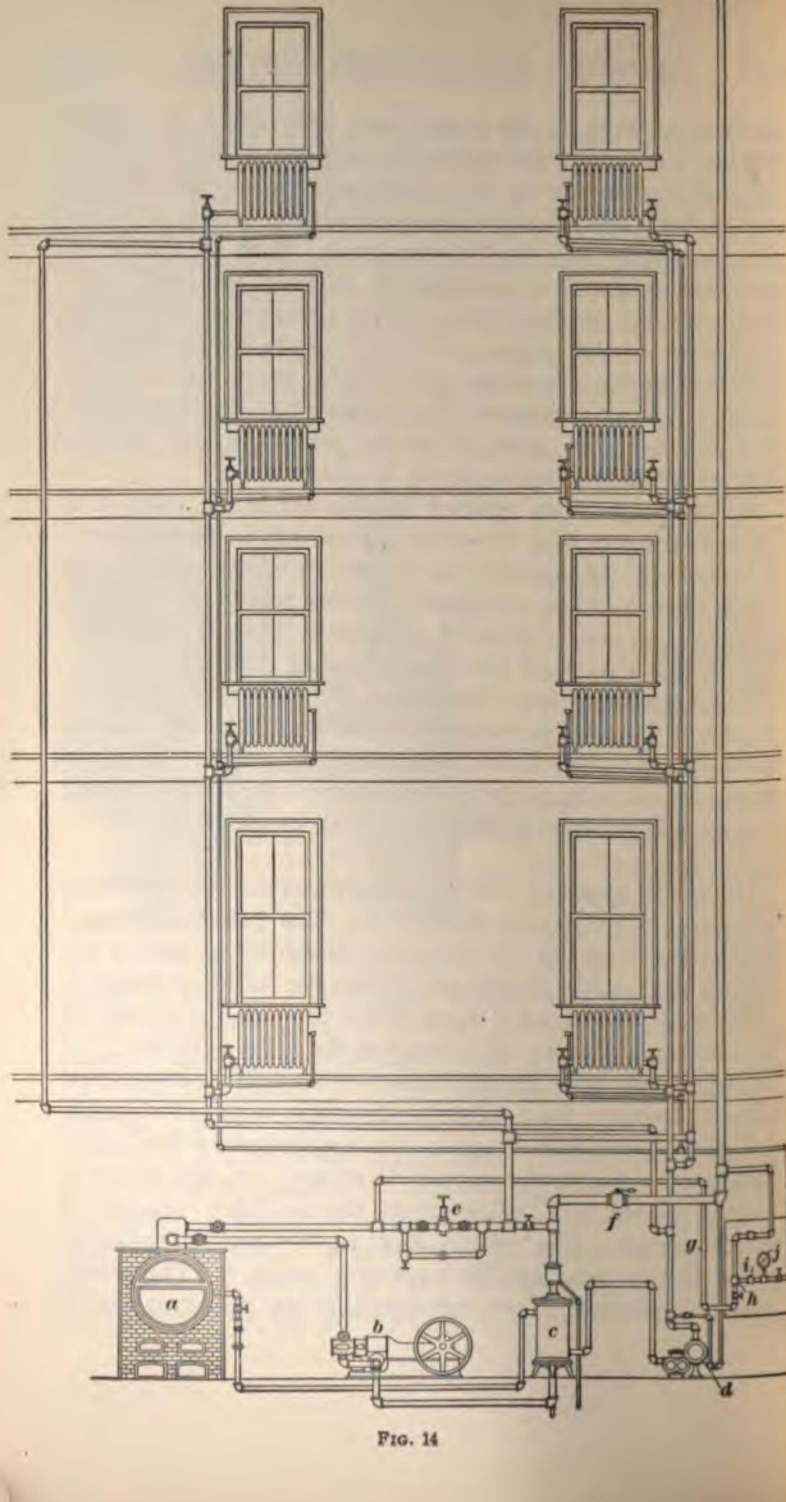


FIG. 14

g. 5. The steam pipe *g* connects to the exhausting apparas *h*, the discharge pipe from which is connected to the haust escape pipe to the atmosphere. The air pipes are nnected to the suction opening in the exhausting apparas *h* and have a check-valve *i* that serves to hold the vacuum the air pipe, a gauge *j* indicating the amount of vacuum tained. The exhausting apparatus and connections are xiliary to regular gravity steam-heating systems to which e apparatus is commonly applied. The radiators shown at e left of Fig. 14 are arranged on the one-pipe down-feed stem, while those at the right are connected up on the twope up-feed system. The system of steam and return pipes practically the same as for ordinary gravity systems, so r as the risers and connections to the radiators and mains e concerned. The air piping *k* is practically the same as ould be erected for gravity systems, with the exception at in the cellar the air pipe is connected to the exhausting paratus of the system.

19. The operation of the system depends on the action a jet of steam under pressure in producing a vacuum in e air pipe by the velocity with which the steam passes rough an ordinary type of ejector, by which the air is hausted from the air pipe and consequently from the radior when the automatic air valves connected to the air pe are open. When the entire system is cold, and before eam is turned on, all the air valves are open. The exhauster started and a partial vacuum is thus created throughout e system. Steam is then let into the radiators and fills em immediately, as there is practically no resistance to the w. The pressure at which the steam flows into the radia- need be equal only to that of the atmosphere. As the diators warm up, the heat of the steam closes the automatic valves, the air pipe remaining closed until the radiator ols and air again accumulates therein, when the operation the air valves is repeated. Thus, in an extensive heatg system, the air that accumulates in the radiators may be ectively drawn off in small quantities by a small ejector.

Owing to the removal of the air, the steam flows to the radiator without any appreciable gauge pressure, the radiator acting as a regular surface condenser, and the air valve operating to allow the cooling air to be extracted as it accumulates.

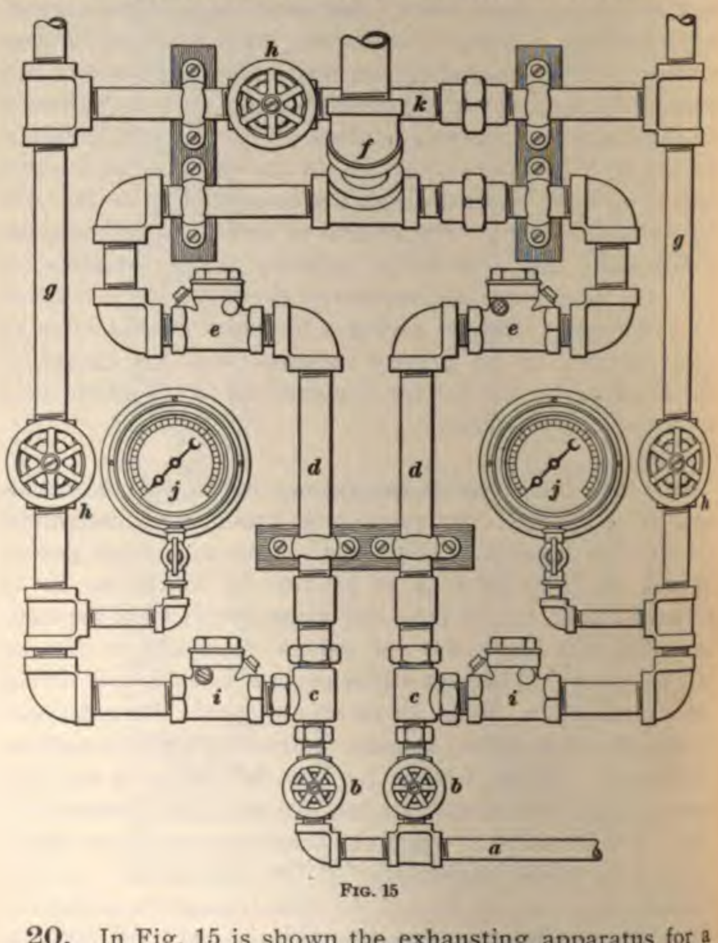


FIG. 15

20. In Fig. 15 is shown the exhausting apparatus for a plant having a large number of radiators, the apparatus being so arranged in duplicate that either ejector may be operated should the other become disarranged. Live steam enters the exhausting apparatus through the pipe *a* and one or both

of the valves b, b, passing to the ejectors c, c, pipes d, d, check-valves e, e, and through f to the exhaust escape pipe. The flow of steam through the ejectors c, c creates a partial vacuum in the air-line piping g, g, through which the air is drawn from the radiators. The valves h, h provide for the independent operation of either half of the apparatus, while the check-valves i, i serve to prevent the establishment of a pressure in the air piping equal to or greater than that of the atmosphere. The vacuum gauges j, j indicate the extent of the vacuum created by the steam in flowing through the ejectors c, c. The valved pipe k serves as a by-pass, by the use of which one ejector may be utilized temporarily in removing the air through both the air lines g, g.

21. An arrangement of the apparatus suitable for use with gravity systems when water pressure is available for exhausting purposes is shown in Fig. 16, the vacuum being maintained through the automatic control secured by using a diaphragm regulator a. The diaphragm chamber being attached to the air-line piping b, when the vacuum therein falls below a given point the valves c and d in the injector connection are opened and the exhauster e reestablishes the required vacuum in the air main. The controlling mechanism consists of an auxiliary valve c attached to the top of the chamber d within which is loosely mounted a differential piston operated intermittently by the pressure of the water that comes through the valve f. When the vacuum in the apparatus is lost, the weights on the end of the regulator arm overbalance the pressure of the atmosphere on the diaphragm, and as the weights descend, the auxiliary valve c is opened. As the discharge or waste water from the auxiliary valve passes away through the small pipe g, the differential piston is forced toward the top of the casing d, thereby opening the lower port therein and permitting the water to flow through the ejector e until the vacuum is reestablished, whereupon the pressure of the atmosphere on the top of the diaphragm of the regulator a lifts the weights and closes the auxiliary valve c. As soon as the discharge

from the auxiliary valve is cut off, the water pressure on top of the piston, which should be from 25 to 30 pounds,

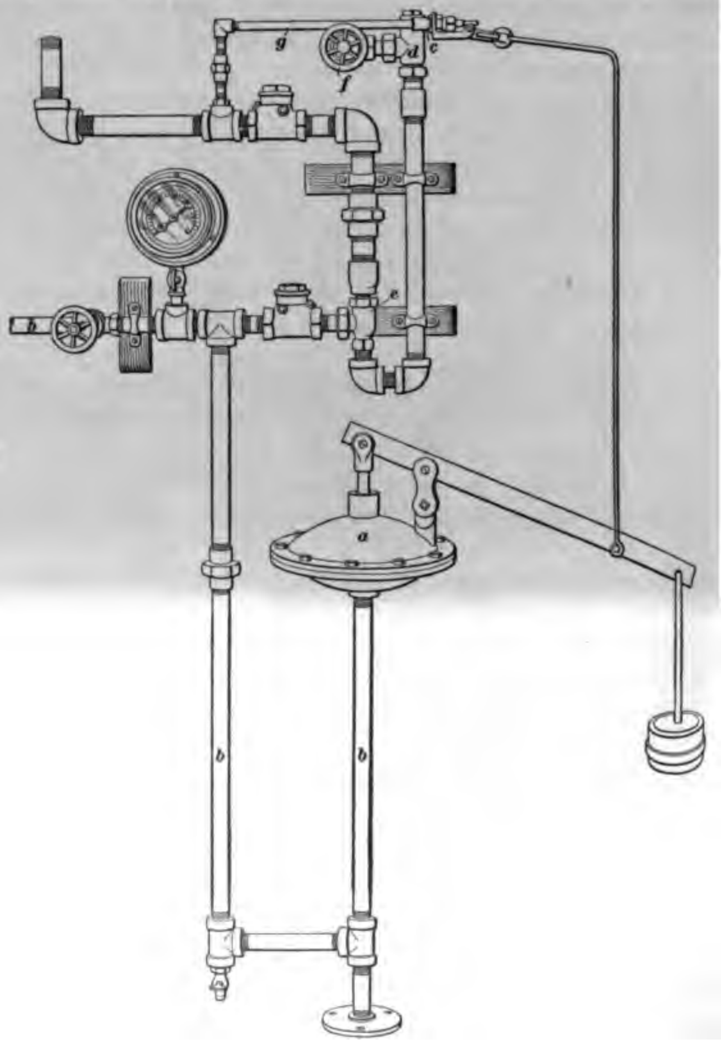


FIG. 16

forces it to its seat and thereby shuts off the flow of water through the exhauster *e*.

In some cases an electrically driven air pump is substi- :ed for the common type of steam-jet exhauster ordinarily ed.

VAPOR SYSTEMS

22. Morgan System.—The general arrangement of ıat is known as the **Morgan system** of steam heating is licated in Fig. 17, which shows the apparatus applied to a e-pipe heating system. One of the distinguishing features this system is the use of a mercury seal trap through

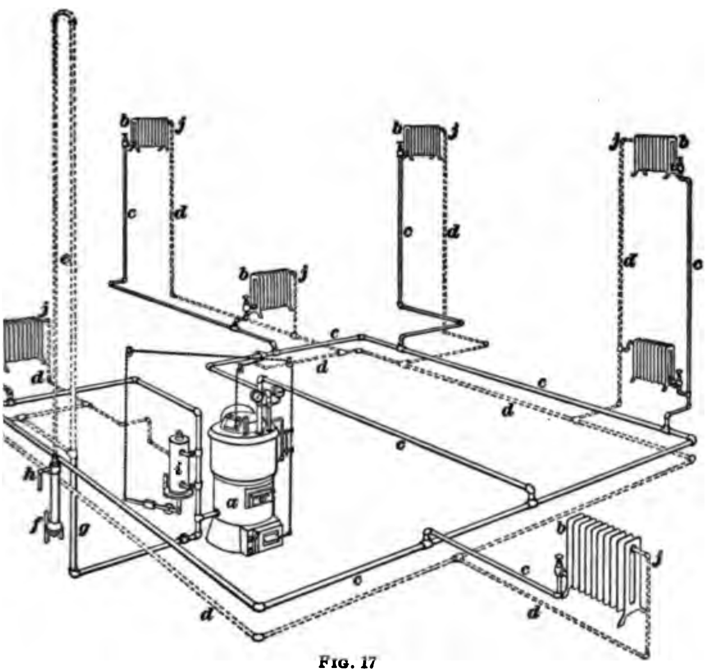


FIG. 17

'hich the air that accumulates in the radiators and piping is ischarged under pressure and by means of which the ɜentrance of air is prevented.

It may here be remarked that under the classification of apor systems are embraced all those in which a natural i. e., as distinguished from forced) circulation of steam

takes place at or slightly below the pressure of the atmosphere, the partial vacuum in the system being created only by condensation, special traps and seals being used to prevent air from entering the piping system after it has been discharged under pressure.

Steam generated in the boiler *a* flows to the radiators *b*, *b* through the pipes *c*, *c*, the pressure of the steam expelling the air from the radiators into the air pipes *d*, *d* through a restricted opening called a *retarder*. While the latter offers comparatively little resistance to the flow of air, the condensation of steam in passing through it causes a drop of water to be deposited therein, and the frictional resistance to the passage of steam is thereby increased. The air piping is run parallel with and in the same direction as the steam piping, the air main in the basement being graded toward the point at which the loop *e* is provided for the purpose of securing a separation of the air and condensation; the air passes up over the loop *e* and then down to the mercury trap *f*, the water of condensation passes to the boiler through the drip pipe *g*, while the pipe *h* serves as a drip and air discharge for the mercury column *f*. While the loop *e* prevents water from reaching the mercury seal, it offers no obstruction to the expulsion of the air.

The height of the loop depends on the maximum drop in pressure, but in practice it is usually made 33 feet. The loop may be placed in any convenient location. The mercury seal, which is placed as near the boiler as may be convenient, prevents the return of air to any part of the system after it has been expelled by the initial pressure generated in the boiler. It holds sufficient mercury to fill the bore of the air pipe to a height of 30 inches under atmospheric pressure without uncovering the lower end of the air pipe. The depth to which the latter is submerged in the mercury seal determines the pressure necessary to expel air through it. The apparatus is arranged so that in case the steam pressure in the boiler is sufficient to cause a temporary discharge of steam through the retarders into the air piping, water of condensation accumulates in the drip pipe *g* and rises

therein so as to cut off communication between the air main and the mercury trap, so that very little, if any, vapor enters the drop leg of the loop to the latter. The application of the apparatus to the two-pipe system is shown in Fig. 18, to which are applied the same letters of reference as are used

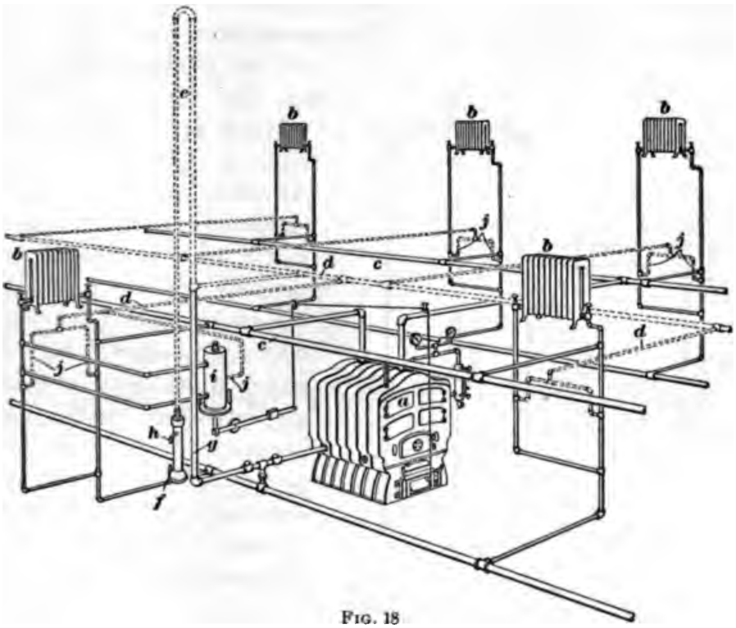


FIG. 18

with Fig. 17. The arrangement of the air piping is slightly different from that shown in Fig. 17, as is also the position of the retarders *j*; otherwise, the systems are substantially the same.

23. The temperature and corresponding absolute pressure of the steam in the boiler are controlled in the Morgan system by means of the special damper regulator *i*, Fig. 17, an enlarged view of which is shown in Fig. 19. It consists of a copper tank *a* in which is placed a brass pipe *b* attached above the boiler water-line to the longest return main, as shown, in order that all the radiation may become heated before the regulator operates to check the fire. The pipe *b*

serves to heat the air in the tank, the air expanding and contracting according to variations in the temperature of the steam in the boiler. In a chamber *c* at the bottom of the tank is arranged a diaphragm, through the actuation of which the lever *d* opens and closes the boiler draft and check-dampers. The lever *d* is fulcrumed at *e* and is provided with an adjustable weight *f* for counterbalancing the weight of the dampers attached to the chain *g*. The valve *h* at the top of the tank is similar in construction to the air valve commonly used on pneumatic bicycle tires. Its purpose is to provide means for testing the regulator, an ordinary bicycle pump being used to pump air into the tank under pressure. This regulator is not required when the operation of the dampers is controlled by the use of thermostats.

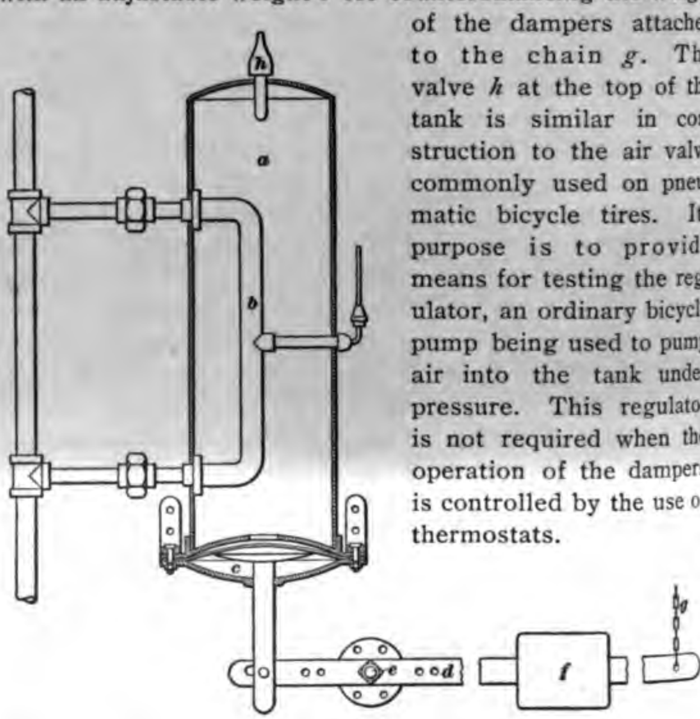


Fig. 19

24. In the Morgan system, the air lines are galvanized-iron pipe. For the riser lines, $\frac{1}{4}$-inch pipe is sufficiently large for connection with six or eight radiators, while the main air lines should not be smaller than $\frac{1}{2}$ inch for ten radiators, $\frac{3}{4}$ inch for twenty radiators, and 1 inch for seventy-five radiators.

25. Trane System.—A mercury seal system in which the main air pipe *a* is connected to the top of the mercury

seal device *b*, is known as the **Trane system**, and is shown in Figs. 20 and 21, the latter being an enlarged sectional view of the mercurial sealing appliance *b*. Automatic operation of the apparatus is obtained by using a thermostat in connection with the diaphragm draft regulator *c*, Fig. 20,

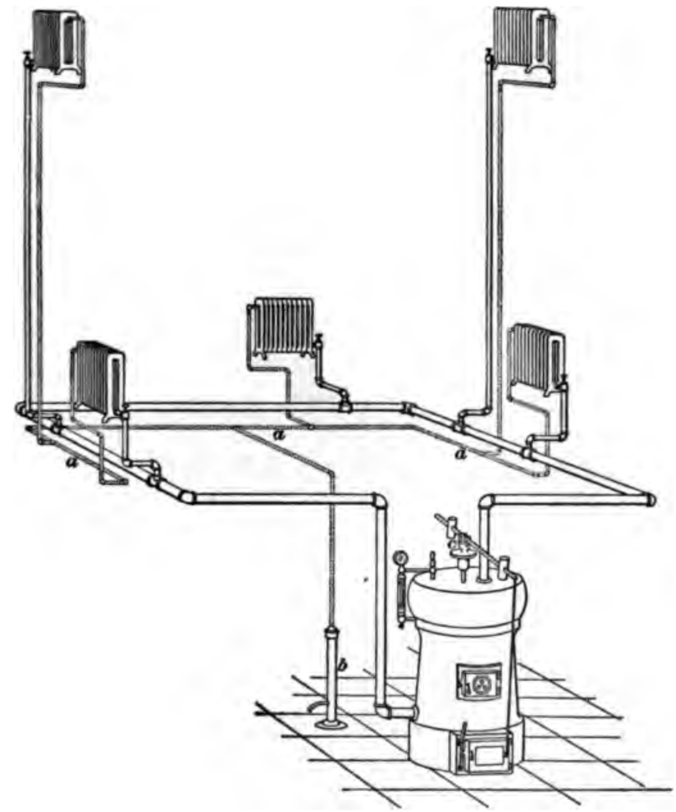


FIG. 20

on the boiler. The weight on the diaphragm regulator is adjusted to the requirements of the weather. Should the weather be cold, it will be found that the draft regulator will maintain a uniform steam pressure for some time before the temperature of the air in the room reaches the point at which the thermostat is set. When the air reaches the desired

temperature, the thermostat immediately closes the necessary electrical circuits for actuating the motor with which the thermostat and lever of the diaphragm regulator are connected. Thereupon the motor closes the drafts, and the thermostat assumes control of the fire, continuing in control until the temperature of the steam becomes too low to supply sufficient heat to maintain the required temperature in the room, when the thermostat transfers the control of the fire to the diaphragm regulator. By the joint action of the thermostat and diaphragm regulator, the steam pressure expels the air and the condensation of steam creates the partial vacuum wherewith the circulation of steam thereafter takes place.

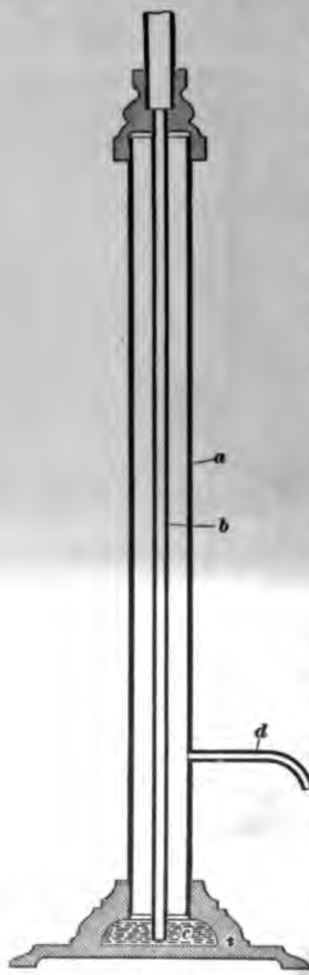


Fig. 21

26. The mercury sealing appliance is shown in section in Fig. 21. It consists of an outer tube *a* and an inner tube *b* through which air from the heating system discharges through the mercury *c*. As long as the air pipe is cold and there is pressure above that of the atmosphere to drive it from the system, the air will be forced through the mercury and out of the orifice *d* in the side near the base of the seal. The use of the mercury seal in connection with a low-pressure steam apparatus, converting the latter into a vacuum heating system, does not prevent the carrying of low pressure

if desired. In fact, the thermostat will repeatedly cause to be carried both a vacuum and a pressure.

27. Each radiator is provided with a thermostatic air valve like that used with the Paul system; and as the air cannot return to the radiators because of the mercury seal, the steam may be maintained at a lower temperature than 212°, owing to the absence of air and the partial vacuum throughout the system due to condensation. When the temperature falls below 212° and a partial vacuum is created, the pressure of the air on the surface of the mercury forces the latter up the mercury tube *b*, Fig. 20, to a height corresponding to the difference between the internal and external pressures. The air valve on each radiator is supplied with a union to which is connected a $\frac{1}{8}$-inch galvanized-iron pipe; this pipe is run in the most convenient or out-of-the-way place, preferably inside the partition, to the basement, where the several air pipes from the radiators are connected to the air main passing around the basement parallel with the steam main. The horizontal branches connecting the air risers to the air main should be at least one size larger than the risers, and the main should not be smaller than $\frac{1}{2}$ inch for 500 feet of radiation, $\frac{3}{4}$ inch for 1,000 to 2,000 feet of radiation, 1 inch for 3,000 feet of radiation.

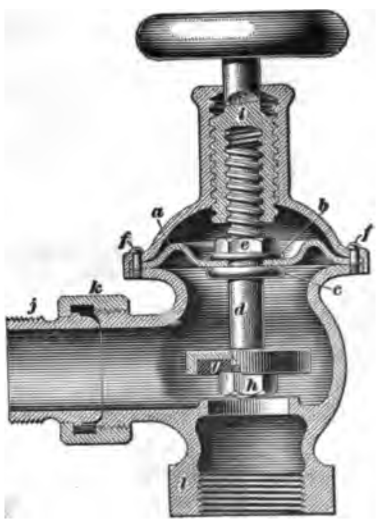


FIG. 22

28. In order to maintain the vacuum created by condensation, it is necessary that the valves and all joints shall be absolutely tight; and since the ordinary types of radiator valve with packed stuffingbox leak sufficiently to destroy the vacuum, it has been found desirable, in practice, to use a special type of valve, like

that shown in Fig. 22, for preserving the vacuum in the system. Entrance of air to the piping system through the radiator valve is prevented by the use of a diaphragm *a* held tightly between the washer *b* and the shoulder *c* on the valve stem *d* by the nut *e*. The outer edges of the diaphragm are clamped tightly between the body and bonnet of the valve, as shown, by means of screws *f*, *f*. The valve is provided with a renewable disk *g* held in place by the nut *h*. Quick operation of the valve is secured by means of a compound valve stem, the upper portion *i* of which has a left-hand thread externally and is threaded right-hand internally to receive the upper end of the stem *d*, thereby securing twice as great a movement of the valve stem as would be obtained with a single screw thread of equal pitch. Connection with the radiator is made by means of the nipple *j* and union *k*, the riser being attached at *l*.

29. Broomell System.—The heating system illustrated in Fig. 23 is known to the trade as the **Broomell vapor system,** the term vapor doubtless being used to indicate the fact that the circulation of steam takes place at or but slightly above atmospheric pressure, to which the tail end of the piping system is open through connection to the boiler smoke flue or chimney. The system has been classified as being of the vacuum type, but it is in reality a low-pressure gravity system, the circulation of steam being due to the drop in pressure resulting from the condensation of steam in the radiators. In fact, it is necessary to maintain a pressure of at least a few ounces in the boiler to insure circulation of the vapor through the radiators.

The steam-supply main *a* is run in the same manner as for the usual gravity steam-heating apparatus. In some cases the main pitches upwards to the extreme end, or, as in Fig. 23, the main is graded downwards to the extreme end, and then brought back to the boiler, forming a circulating main system, with the return *b* above the boiler water-line. The water of condensation from the radiators flows back to the boiler through the separate dry-return main *c*. The return

main *b* might be utilized for this purpose by using loop seals as drip connections between the steam main and the main return, the seals being made deep enough to counterbalance the difference in the pressures. The rising lines and branches to the radiators are similar to those of any two-pipe heating system, the pitch of the radiator branches being sufficiently great to drain effectively to the risers or mains without trap-

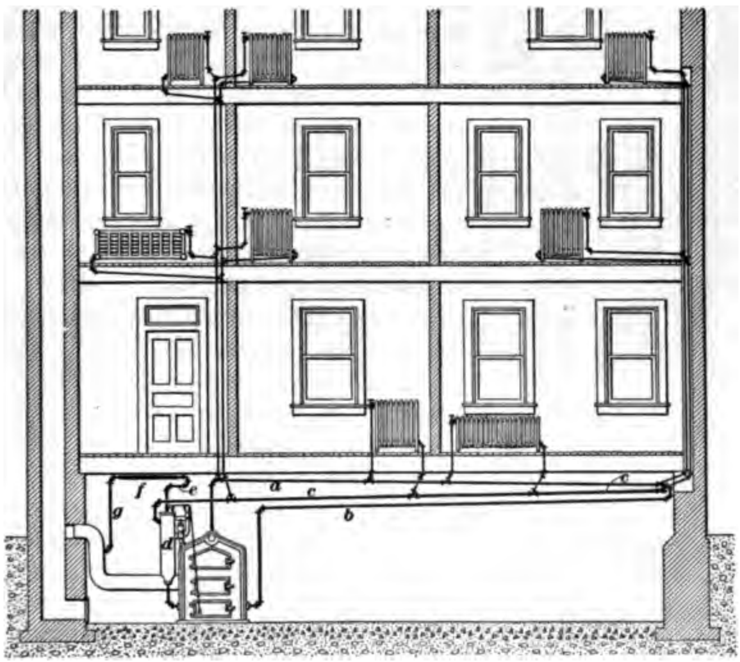


FIG. 23

ping the connections. The return pipe *c*, which should be at least 4 feet, and as much higher as possible, above the boiler water-line, as the pressure in the boiler may vary, is connected as a dry return to the top of a receiver *d*, whose construction is shown in detail in Fig. 24. A vapor pipe *e*, Fig. 23, is also connected to the top of the receiver and leads to the condensing coil or radiator *f* and escape pipe *g*. The condensing coil will condense any vapor that might pass through the

receiver, to which the condensation drains back. The outlet pipe from the condensing coil is run into the smoke pipe or chimney, the idea being that if the chimney has a good draft, air will be drawn from the coil and a partial vacuum thereby created. Under ordinary conditions, however, it will be found in practice that the sucking or aspirating influence exerted by the chimney is too slight to be effective in drawing air from the piping system.

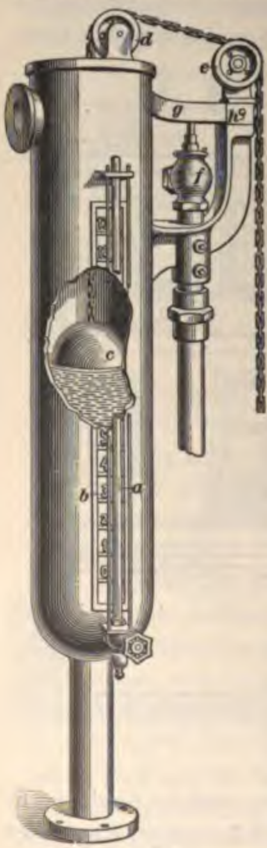


FIG. 24

30. As shown in Fig. 24, the round cast-iron receiver *d* of Fig. 23 is provided with a gauge glass *a* behind which is a scale *b* graduated to show ounces of pressure as represented by the height of the water column in the gauge glass. A copper float *c* within the receiver is attached, by a brass chain that passes upwards through an opening in the hinged cover of the receiver and then over the pulleys *d* and *e*, to the draft damper in the ash-pit door of the boiler. A special type of safety valve *f* is placed in the connection to the steam space of the boiler at the right of the receiver. A weighted lever *g*, fulcrumed in the supporting bracket *h* and resting on top of the safety-valve stem, as shown, projects into the top of the receiver. The latter is connected up so that when there is no pressure on the system the water stands at the same level in both boiler and receiver, showing in the gauge glass at the zero mark on the scale of the latter. When steam is generated and pressure thereby produced in the boiler, water of condensation collects in the receiver until the difference in pressure in the system is

overcome, when the water flows from the receiver into the boiler by gravity. The float *c*, by means of which the operation of the damper is controlled, is set according to the character of the weather, by shortening or lengthening the damper chain, so that the draft damper will close at any desired difference or drop in pressure within the limits for which the receiver may be designed. If, when the water rises to the point at which the float has been set to close the draft damper, the steam pressure continues to increase, the float rises until it comes in contact with the safety-valve lever, lifting it and permitting the valve to open and thereby relieve the pressure in the boiler. Thereupon, the water in the receiver falls, and if it descends beyond the point at which the float is set to close the damper, the latter will be opened. In order that this damper regulating apparatus may operate satisfactorily, it is essential that the ash-pit damper be light and easily moved, the fire and ash-pit doors being kept closed to secure automatic regulation of the boiler pressure.

31. In the Broomell system the steam-supply connection to the radiator is at the top, where the special regulating valve illustrated in Fig. 25 is used to control the amount of steam admitted to the radiator. This is accomplished by providing in the valve disk *a* a series of four $\frac{1}{8}$-inch or $\frac{1}{4}$-inch circular ports, as *b*, adapted to correspond with similar steam-admission ports, as *c*, and an air or venting port *d* in the valve seat. The disk *a* is held to its seat by the spring *e*, which also serves to hold the shoulder near the top of the valve stem *f* in close contact with the ground joint surface *g*, thereby obviating the use of packing. To the extreme upper end of the valve stem is attached the lever arm *h* through which projects the pin *i* of the handle *j*, by which the lever arm *h* is moved to turn the steam on or off. Sockets, as *k*, whose position in the cap or head-plate *l* corresponds to that of the feed-ports in the valve seat, are provided for the reception of the pin *i*, which may be locked in position by means of a locking screw *m* after adjusting the valve disk. When the steam is entirely shut off from the radiator, the

fourth port in the valve disk comes over the air port *d*, through which communication with the atmosphere is established, thereby destroying the partial vacuum that may exist in the radiator and preventing the possibility of water being backed

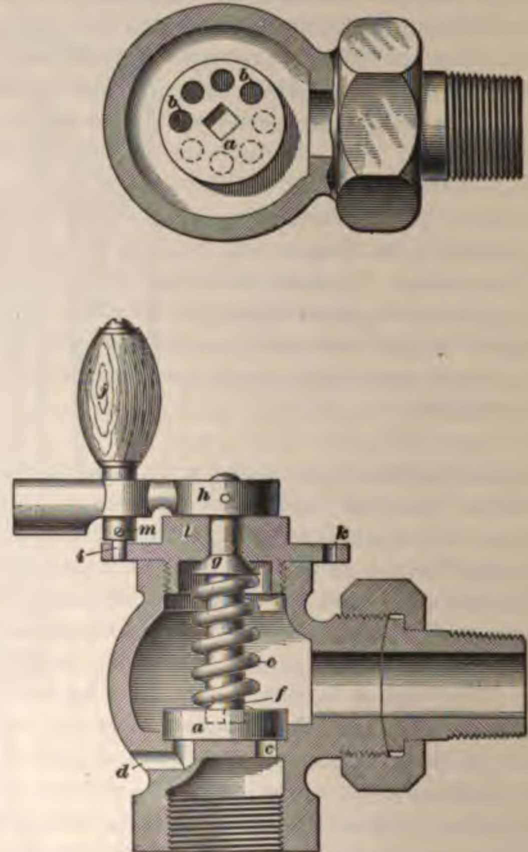


FIG. 25

up in the return pipe. By turning the valve stem so that the pin *i* occupies the first socket from that which represents the closed position of the valve, the air port *d* will be closed and the first port in the valve disk will come over the first feed-port in the valve seat, and so on, the valve disk being turned,

is required, to bring the ports successively over each other until the valve is fully opened.

32. The return connection at the bottom of the radiator is provided with a special union connection having a water pocket in it to cause the steam to fill the radiator completely and prevent one radiator from drawing vapor from another when the radiator is shut off. In operation, steam under a slight pressure is admitted to the radiator in small or large quantities to heat as much of the surface of the radiator as may be required. If the temperature desired in the room is 60°, a small quantity of steam may be admitted; if a higher temperature is wanted, a little more steam may be admitted. The steam condenses in the radiator, and the water of condensation, which falls to the bottom of the radiator, passes through the special water-seal pocket in the return main and thence into the return pipe. As there is no back pressure on the return pipe, the water flows into the receiver *d*, Fig. 23, where it accumulates until it attains a sufficient head to flow by gravity into the boiler. The return mains are open to the atmosphere through the receiver and condensing coil employed to prevent the escape of vapor from the return mains through the escape pipe. The boiler may be of any one of the types on the market, provided the headroom above the boiler is sufficient for the required difference of level to be maintained between the water in the receiver and that in the boiler.

33. The Broomell system may be adapted to use where exhaust steam from engines, etc. is available, in which case the return pipe would be brought to the engine room and a condensing coil attached to the top of the return pipe, the water from it draining into a receiver. The vapor pipe would be connected to the chimney, and the water of condensation pumped back to the boiler.

34. Thermograde System.—A modification of the system shown in Fig. 9, with the return risers fitted with a vapor pipe to the roof, and with traps on the radiator return pipes, as in Fig. 8, is known as the **thermograde system.**

The autovalve may quickly be cleared of scale and of sediment by lifting the handle *f* attached to the rod *g*, thus raising the valve to an emergency position and allowing the full pressure of steam to sweep over the seat, this being done without disarrangement of the adjustment of the valve. The autovalve can be acted on by steam only, there being no danger of the hot water of condensation surrounding the zinc tube to cause expansion, since the moment water rises above the valve seat, it is drained into the returns through two openings, one of which is shown at *h*.

SPECIAL APPLIANCES

36. Numerous special appliances have been designed for use in connection with vacuum systems of heating for securing a discharge of air from the radiators and, by preventing the entrance of air to the radiator, for preserving the partial vacuum obtained by condensation. For this purpose air valves have been constructed with small check-valves in the air-discharge orifice, so that the air will not return to the radiator after it has been driven out by the pressure of the steam. These valves are not quite so successful as they are designed to be, as the apparatus to which they are sometimes attached is faulty in construction, and the use of these valves aggravates the trouble. Air valves with this attachment should be used only with the one-pipe system. When such devices are used, the radiators must be of ample size, in order to heat the whole house with a low pressure, and the pipes must be run so as to equalize the flow of steam; otherwise, one or more radiators will not get a sufficient amount of steam, the rapid condensation in some of the radiators drawing steam from other points, while the velocity of the inflow of steam will hold back the condensed water in the radiator.

37. One of the special devices used with vacuum systems is the **Allen automatic air and vacuum valve**, shown in Fig. 27. This appliance was especially designed for use on low-pressure and exhaust steam-heating systems that may be

operated under a partial vacuum in order to secure the advantage of a low temperature in mild weather. The valve permits the escape of air from the radiator, closing automatically against the emission of steam or water and preventing the ingress of air to the radiator. The valve proper comprises an outer shell *a* within which a partition is so placed as to form a well *b* in the lower part of the valve to receive and retain the water condensed from the steam as it passes into or through the valve. A sealed metal float *c* is placed in this well. The outer chamber is connected with the inner chamber by means of a small hole *d* near the bottom of the inner shell. The top of the valve chamber is provided with a double-seated bushing *e*, the pin *f* on top of the float *c* engaging with the lower seat, while the upper seat receives the vacuum pin *g*. Attached to the top of the vent is a diaphragm chamber containing a corrugated metal diaphragm. To the upper part of the radiator connection a small pipe *h* is attached by means of a union nut *i*. This pipe forms a direct connection between the radiator and the bottom of the diaphragm chamber *j*. To the upper side of the diaphragm *k* is attached a small rod *l* to which in turn a stamped metal hood *m* is fastened by means of a screw and locknut. The

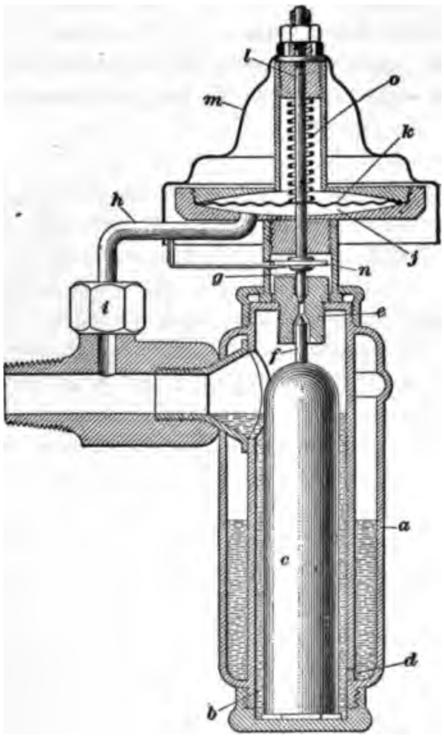


FIG. 27

vacuum pin *g* is fastened to a small bar *n*, which in turn is fastened to the bottom of this metal hood. To insure proper seating of the vacuum pin, a spring *o*, pressing down on the diaphragm, is used. On the upper part of the spring is a small screw by means of which any desired pressure on the vacuum pin can be obtained. Unless otherwise ordered, these screws are so adjusted as to resist a pressure against the diaphragm of $\frac{1}{2}$ pound. When the pressure exceeds $\frac{1}{2}$ pound, the vacuum pin unseats, allowing the air to be freely vented through the valve, in the same manner as would be the case if the vacuum attachments were not used. When the pressure falls below $\frac{1}{2}$ pound, the pressure of the spring *o* forces the vacuum pin *g* to its seat, thereby preventing any air from returning to the system or the radiator through the air valve.

During the first operation, as soon as the pressure reaches $\frac{1}{2}$ pound or over, the pressure communicated through the small pipe *h* raises the diaphragm *k*, and with it the vacuum pin *g*, unseating the latter and allowing the air to pass freely through the opening thereby uncovered. As long as the pressure on the diaphragm exceeds $\frac{1}{2}$ pound, the vacuum pin remains unseated. When steam enters the air valve it condenses and gradually fills the inner well *b* with water, carrying the float pin *f* to its seat, thus closing the valve against the emission of steam. The steam that first enters the valve requires a few minutes to condense sufficient water to close the valve. During the first operation, the air in the outer chamber of the valve is expanded by the heat of the steam and a portion of it is expelled through the small hole in the inner chamber and thence out of the valve through the regular outlet. As the inner chamber fills with water from condensation, the outlet *d* becomes sealed by water. When steam is shut off, and the valve cools, the air in the outer chamber contracts, draws the water from the inner chamber *b*, and allows the float *c* to drop, thus opening the air valve. When steam again enters the valve, the heat expands the air in the outer chamber, forces the water into the inner chamber, carries the float pin to its seat and closes the valve against the emission of steam. The operation of the valve

proper is always the same whether the pressure is 1 pound or 10 pounds. The greater the pressure the higher the temperature, but the only effect this condition has on the valve is simply to expel a little more of the air from the outer chamber of the valve. When the valve cools, the contraction of the air in the outer chamber draws the water from the inner chamber and then draws air through the water until the outer chamber is fully recharged. When cold, the condition of the valve is always the same. No adjustment is necessary at any time.

HOT-WATER HEATING SYSTEMS

DESIGN AND ARRANGEMENT

FUNDAMENTAL PRINCIPLES

INTRODUCTION

1. The diffusion of heat in fluids is accomplished by conduction. In liquids and gases, the process is aided by the motion of the particles of the substance among themselves. The tendency of convection currents is to merge into streams or currents of considerable magnitude. The movement of these large principal currents is called **circulation.** The rapidity of circulation will depend on the following considerations: (1) The amount of heat received per minute on a given area of surface; (2) the extent of the heating surface in proportion to the volume of the fluid; (3) the place of application of the heat, whether at the top, side, or bottom of the mass; (4) the conductivity of the fluid:

2. The volume of water does not increase at the same rate as the temperature; the expansion has been determined by experiment, and the results are given in Table I.

The increase in volume caused by heating water, or in height of a column of uniform cross-section, may be computed by the following:

Rule.—*Multiply the volume, or height of column, at the lower temperature by the difference in the comparative volumes at the original and final temperatures.*

TABLE I

EXPANSION OF PURE WATER

Temperature Degrees Fahrenheit	Comparative Volume Water at 32° = 1	Comparative Density Water at 32° = 1	Weight of 1 Cubic Foot Pounds	Temperature Degrees Fahrenheit	Comparative Volume Water at 32° = 1	Comparative Density Water at 32° = 1	Weight of 1 Cubic Foot Pounds
32.0	1.00000	1.00000	62.418	135	1.01539	.98484	61.472
35.0	.99993	1.00007	62.422	140	1.01690	.98339	61.381
39.1	.99989	1.00011	62.425	145	1.01839	.98194	61.291
40.0	.99989	1.00011	62.425	150	1.01989	.98056	61.201
45.0	.99993	1.00007	62.422	155	1.02164	.97882	61.096
46.0	1.00000	1.00000	62.418	160	1.02340	.97714	60.991
50.0	1.00015	.99985	62.409	165	1.02589	.97477	60.843
52.3	1.00029	.99971	62.400	170	1.02690	.97380	60.783
55.0	1.00038	.99961	62.394	175	1.02906	.97193	60.665
60.0	1.00074	.99926	62.372	180	1.03100	.97006	60.548
62.0	1.00101	.99899	62.355	185	1.03300	.96828	60.430
65.0	1.00119	.99881	62.344	190	1.03500	.96632	60.314
70.0	1.00160	.99832	62.313	195	1.03700	.96440	60.198
75.0	1.00239	.99771	62.275	200	1.03889	.96256	60.081
80.0	1.00299	.99702	62.240	205	1.04140	.96020	59.930
85.0	1.00379	.99622	62.182	210	1.04340	.95840	59.820
90.0	1.00459	.99543	62.133	212	1.04440	.95750	59.760
95.0	1.00554	.99449	62.074	230	1.05290	.94990	59.360
100.0	1.00639	.99365	62.022	250	1.06280	.94110	58.750
105.0	1.00739	.99260	61.960	270	1.07270	.93230	58.180
110.0	1.00889	.99119	61.868	290	1.08380	.92270	57.590
115.0	1.00989	.99021	61.807	298	1.08990	.91750	57.270
120.0	1.01139	.98874	61.715	338	1.11180	.89940	56.140
125.0	1.01239	.98808	61.654	366	1.13010	.88500	55.290
130.0	1.01390	.98630	61.563	390	1.14440	.87380	54.540

Or, $$I = V(a - b)$$

where I = increase of volume or height;
V = original volume or height;
a = comparative volume at final temperature;
b = comparative volume at original temperature.

EXAMPLE 1.—A heating apparatus contains 300 cubic feet of water at 60° F.; how much will the water expand if the temperature is raised to 230° F.?

SOLUTION.—By Table I, the comparative volumes are 1.00074 and 1.0529, respectively. Applying the rule,

$$I = 300 \times (1.0529 - 1.00074) = 15.648 \text{ cu. ft. Ans.}$$

EXAMPLE 2.—A vertical pipe is filled with water to a height of 32 feet; how many inches will the water rise on being heated from 65° F. to 180° F.?

SOLUTION.—The comparative volumes at 65° and 180° are 1.00119 and 1.031, respectively, by Table I. Applying the rule,

$$I = 32 \times 12 \times (1.031 - 1.00119) = 11.48 \text{ in., nearly. Ans.}$$

Water is practically incompressible, and it expands with as much force as ordinary metals; when heated or cooled, the vessel or pipes that contain it expand or contract also, but in a less degree.

PRINCIPLE OF HOT-WATER CIRCULATION

3. The principle underlying the circulation of water in a gravity hot-water heating apparatus may be illustrated by means of the apparatus shown in Fig. 1, which consists of two glass tubes, or vessels, A and B, connected near the top by the tubes a, a, and at the bottom by the tube b, a stop-cock c being placed in a, a. The tubes A and B are nearly filled with water and the water level in each tube is marked by two points d and e. The surface of the water in A will be level with the surface of the water in B because the water is of uniform density, and the tubes A and B are joined. Assuming that the tubes A and B are of precisely the same shape and sectional area, the volume and weight of water in each tube is the same.

Now, close the cock c and ignite the Bunsen burner f, placing it under the column A, and thus apply heat to the

water. As the water in the base of A receives heat from the flame, the heated particles are pushed upwards toward the surface by the colder particles, which also rise when heated. No perceptible currents are established by this rising of the heated particles and falling of the colder ones, because the upward movement of the heated particles is so interfered with by the downward movement of the others that the warm and cold particles are mixed together and thus tend to produce a uniform temperature throughout the whole body of water.

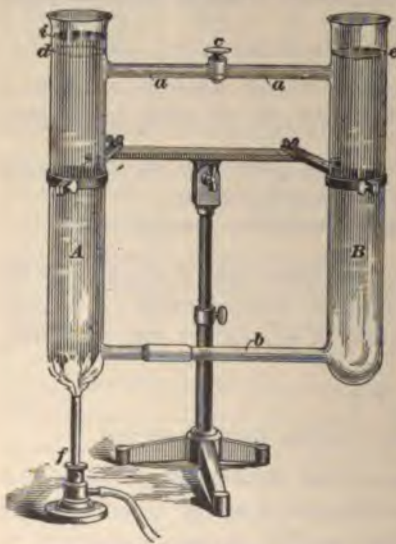


FIG. 1

As the water in A becomes heated it will expand, that is, increase in volume, but its weight will remain unchanged. Since the tube A remains practically unchanged in shape and dimensions when heated by the water, it follows that the increase in the volume of the water in A must either cause the water to rise in the tube, or travel through the connecting tube b, and so raise the lever of the water in B or in both A and B. By continuing the application of heat, it is observed that the increase in volume causes the water in A to rise above the point d, while the water-line in B remains at the point e, as shown in the figure. This is due to the fact that although the hydrostatic head, that is, the depth of the water, is greater in A than in B, still the difference in density of the water in the two tubes compensates for their difference in height, and so the pressure at the base of each is the same. The vertical distance between the new surface i of the water in A and the old water level d, will vary with the temperature of the water in A and the

height of the original column; it will increase with an increase of temperature (not with a constant ratio, however) and in the proportion of any increase in the height of the columns *A* and *B*.

4. Suppose that the original height of the column in *A* was 10 feet, the temperature of the water 46° F., and that it is heated to 200° F. Then, by the rule in Art. **2**, the vertical distance between the surface of the water in *A*, Fig. 1, and the old water level at *d* is $10 \times 12 \times (1.03889 - 1) = 4.67$ inches, nearly. This means that at the level *d* there exists a pressure that is greater than that of the atmosphere by an amount equal to the pressure exerted at the base of a column of hot water 4.67 inches high, while the pressure at the level *e* in the column *B* is that of the atmosphere only. Hence, while the pressures at the bases of *A* and *B* are equal, the pressures at the two sides of the stop-cock *c* in the tubes *a*, *a* are unequal, so that when *c* is opened hot water will flow from *A* into *B*. The water level in *B* is raised thereby and lowered correspondingly in *A*; this increases the pressure at the base of *B* and decreases the pressure at the base of *A*. Since *A* and *B* are joined by the tube *b* at the bottom, cold water will flow from *B* through *b* into *A* to balance the inequality of pressures between the two water columns. The exchange of hot and cold water between *A* and *B* will continue until the average density of the water in the two columns is exactly equal, when the flame is removed. However, as long as heat is applied to one of the two columns, circulation will continue.

This experimental demonstration shows that in a hot-water heating system the primary cause of water circulation is the cooler water in one part of the apparatus pushing the warmer and lighter water in another part to the top.

MOTIVE FORCE

5. The force that causes the water in a hot-water heating system to flow is often called the **motive column**, and is the pressure due to the head of water between the levels *d*

and i, Fig. 1. Whether the motive column is actually present, as in an open apparatus, such as is shown in Fig. 1, or whether it is only imaginary, as in a closed apparatus, where the water expands into an expansion tank, a difference in pressure equal to that exerted by the motive column will always be present.

It should be clearly understood that hot water will move only when there is a heavier and cooler body of water to displace it and force it upwards by means of its superior weight, or when some force, other than the force of gravity, is employed to move it. The driving force that propels the water in any given circuit operating by gravity alone is proportional to the difference in the mean temperatures of the ascending and descending parts of the circuit, and does not depend on the actual quantity of water contained in those opposing parts of the system. With a given difference in temperatures, the motive force is also proportional to the vertical height of the circuit. Thus, the motive force, or head, in a circuit 50 feet high, is twice as great as in one only 25 feet in height.

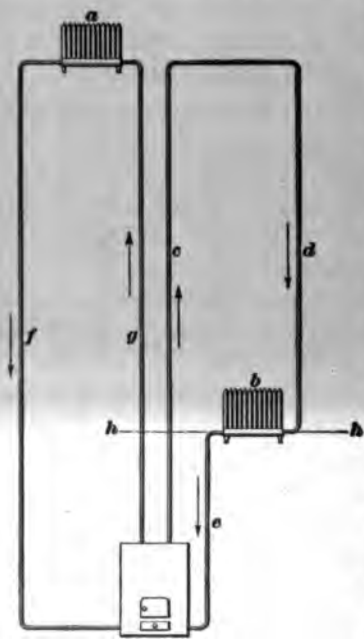


FIG. 2

6. The force of the circulation through radiators, etc., with a given fall of temperature, depends chiefly on the height of the return column, and is, in many cases, practically independent of the height of the supply column. Thus, in Fig. 2, the circulation through the radiator a will be about three times as great as through b, notwithstanding the fact

that the supply columns *c* and *g* are of equal height, because the return *f* is about three times as high as the return *e*. The temperature in the pipes *c* and *d* is supposed to be nearly the same; consequently, the column *d* simply balances an equal height of column *c*, and fails to supply any force for circulation. The force for circulation in this circuit, therefore, depends on the excess in density of the water in *e* over that contained in the riser below the level of the radiator at the line *h*.

It will be seen that the only way in which the drop pipe *d* can be of service is to act as a cooler, and thus lower the temperature of the water it contains.

7. While it is true that the total motive force increases with the size of the pipe, that is, the motive force in a pipe 4 inches in diameter will be four times that in a pipe 2 inches in diameter, yet it must be remembered that the 4-inch piping contains four times as much water to be moved as the 2-inch pipe, so that the force exerted, and the water the force is exerted on (in other words, the power and the resistance), are relatively the same. It is, therefore, a mistake to suppose that by increasing the size of the pipe there is secured an increase of motive force with which to overcome faults in piping, or such resistances as arise from obstructions in the form of foreign matter. Every increase in the size of pipe means an increase in the quantity of water to be moved, and there is, therefore, no motive force to be wasted in any size of piping. However perfectly the piping is proportioned and run, the margin in motive force is so narrow that extremely slight obstructions will render the apparatus practically inoperative.

8. The force available for moving the water in a gravity hot-water heating system may be computed by the following method: The height of the descending column should be measured from the actual top of the column (the point at which the water begins to flow downwards) to the point where the return pipe enters the boiler. The average temperatures of the ascending and descending columns should

then be carefully measured. The difference in weight of columns of water 1 inch square and 1 foot high, at the actual average temperatures thus found, may be learned by using columns 4 and 8 of Table I. As these columns give the weight of the water per cubic foot, however, it is necessary to divide by 144 in order to obtain the weight or pressure per square inch for each foot in height. This difference in weight between the ascending and descending columns of water, when multiplied by the height of the columns, in feet, equals the total pressure per square inch that acts as a motive force to drive the water forwards.

EXAMPLE.—What is the total motive force per square inch in a hot-water heating apparatus, when the average temperature throughout the ascending column is 230°, and in the descending column 180°, the operative height of the descending column of water being 70 feet?

SOLUTION.—Table I shows that water at 180° exerts a pressure of $\frac{60.548}{144} = .4205$ lb. per sq. in. at the base of the column for each foot of height; and that water at 230° has a corresponding pressure of $\frac{59.36}{144} = .4122$ lb. per sq. in. The force available for moving the water will then be the difference in pressure multiplied by the height of the column, which is $.4205 - .4122 = .0083$ lb., and $.0083 \times 70 = .581$ lb. per sq. in. at the base of the column. Ans.

In estimating the operative height of the column, any part of the system that is located above the level of the point at which the water begins to flow downwards must not be included. The elevation of the level of the water in the expansion tank above that point does not increase the motive force of the system in any degree. It serves only to increase the static pressure equally throughout the whole system. An increase of static pressure simply raises the boiling point of the contained water, and thus admits of a higher temperature being given to the water in circulation.

EXAMPLES FOR PRACTICE

1. What will be the height of a column of water when heated to 200° F. from 60° F., the height of the original temperature being 24 feet? The column is uniform in cross-section.

Ans. 24.92 ft., nearly

2. If 42 gallons of water is heated from 32° F. to 175° F., what will the new volume be? Ans. 43.221 gal., nearly

3. In a hot-water heating system, the ascending column averages 180° F. and the descending column 140° F.; the descending column being 45 feet high, what is the motive force, in pounds per square inch? Ans. .26 lb. per sq. in.

CIRCULATION IN RADIATORS

9. Hot-water radiators may be supplied with hot water at the top or at the bottom, but the pipe that returns the water from a hot-water radiator to the boiler should be connected to the bottom tapping of the radiator. If the hot water is introduced at the top, the circulation of the water within the radiator will be downwards in every loop or section, the sections being connected together with nipples at the top. As the water becomes cooled in the sections, it falls by gravity to the return pipe. If the hot water is introduced into the base of the radiator, it invariably ascends in the loops nearest the inlet tapping and descends in the other loops. If the radiator is short, the circulation may be up one column of each loop and down the other column; or, the direction of the circulation may be both ways in the same radiator. . In any case, the general direction of the current must be from the inlet tapping to the outlet tapping. The circulation within the sections is of secondary importance and does not materially affect the efficiency of the radiator.

ARRANGEMENT OF APPARATUS

APPLIANCES REQUIRED

10. The apparatus required for warming buildings by the use of hot water is essentially composed of a water heater, often called a **hot-water boiler**, a number of radiators or other such heating surfaces, and a system of piping to connect the radiators to the water heater. An expansion tank is also employed in the system for the purpose of compensating for the expansion or contraction of the water due to the changes in its temperature.

The boiler, or heater, is generally located in the basement or cellar of the building to be warmed, and, if possible, lower than the lowest radiators to be heated. The reason for setting the boiler low is that the hottest water always flows to the highest parts of the system, and the lower radiators, particularly if below the level of the boiler, are liable to be too cool to become efficient heating surfaces.

The piping usually consists of two systems, a **flow system**, or that which conveys the hot water from the boiler to the different radiators, and a **return system**, or that which conveys the water from the radiators back to the boiler. All the flow pipes should, if possible, pitch gently upwards toward the radiators to which they are connected, and the return pipes should have the same pitch. This will not only prevent air from accumulating at any point in the piping, but will also facilitate the circulation of the water.

Owing to the fact that water, whether hot or cold, will flow in the direction of least resistance, it is absolutely necessary that the pipes be properly proportioned to take to the several radiators exactly the volume of water required, and no more; otherwise, more water will flow through some radiators than through others, which means that some radiators will be hotter than others.

Small air valves, automatic or otherwise, are attached to the highest points of the several parts of the system, usually on or near the tops of the radiators, to allow air in the system to escape, and thus prevent a stoppage of circulation by air locks.

11. Water, when heated in the boiler, rises in the flow main and its several branches and enters the radiators through hot-water radiator valves. While circulating through the several sections or loops of the radiators, the hot water parts with some of its heat to the surrounding atmosphere, thus being lowered in temperature and, consequently, increased in density; it then returns to the boiler through the several return risers and return main and becomes reheated in the boiler, to rise and again flow to and through

the several radiators, where it is again cooled, and once more returns to the boiler for more heat. Thus, it will be seen that the water in a hot-water heating apparatus is simply a medium for conveying heat, from the burning fuel in the boiler furnace, to the air in the rooms. It will also be seen that a constant circulation of the hot water is necessary to maintain the temperature of the radiators above that of the air surrounding them. If the circulation through a radiator is checked by partly closing the radiator valve, the mean temperature of the radiator will be reduced and the temperature of the room can thus be regulated.

The necessity of having some kind of an expansion tank attached to a hot-water system becomes apparent when it is considered that the capacity of the heater, the pipes, and the radiators, practically remains the same, while the water increases in volume when it is warmed above the point of maximum density, 39.2° F., and decreases in volume as it is decreased in temperature, until it reaches 39.2° F.

EXPANSION TANKS

12. The object of using an **expansion tank** in a hot-water heating apparatus is simply to have a receptacle into which the water in the heating system may expand when heated. If an open expansion tank is employed, the expansion of the water takes place without any perceptible change in the pressure throughout the system. If a closed tank is employed, however, the water in expanding will compress the air in the tank, thereby increasing the pressure throughout the system and raising the boiling point of the water; for instance, the boiling point of water at the sea-level pressure of 14.7 pounds is 212° F., while the boiling point of water subject to a gauge pressure of 60 pounds per square inch is about 307° F.

13. To compute the size of an expansion tank, it is first necessary to find the capacity of the heating apparatus, and then how much the water will expand when heated from 46° F. to the highest temperature possible for the pressure

to which the water will be subjected. When the tank is open, it is customary to calculate on a maximum temperature of 212°, although the temperature of the water in the heater may be much higher, due to the pressure corresponding to the hydrostatic head; that is, to the depth of water between the expansion tank and the boiler. When the tank is a closed one, the amount of expansion is usually calculated from 46° F. to the boiling point at a pressure equal to the highest pressure that will ever exist in the expansion tank.

The amount of expansion for a given system, that is, the change in volume of the contained water, is calculated by the rule in Art. 2, and this should be the minimum capacity of an expansion tank. Thus, suppose that the capacity of the water heater, the piping, and the radiators is 300 gallons, and that an open expansion tank will be used. Then, by Table I, the relative volumes at 46° and 212° are 1 and 1.0444, respectively. Applying the rule in Art. 2, the expansion is $300 \times (1.0444 - 1) = 13.32$ gallons, which should be the minimum capacity of the tank.

Having computed the actual volume required for the expansion of the water, the additional space for air may be readily found. The pressure of steam having a temperature of 350° is about 135 pounds absolute. Air must be compressed to about one-ninth of its original volume to produce that pressure; therefore, the space for air, above high-water mark, should be one-ninth of that allowed for the expansion of the water.

The dangers pertaining to the use of the hermetically sealed tank are so great that their use is unjustifiable. In all cases where a closed tank is employed, a proper safety valve should be attached.

14. A common and simple method of proportioning an open tank to a heating apparatus is to make the tank capacity 5 per cent. that of the apparatus. This is done on some of the best work and gives good results.

The size of the closed tank depends considerably on the highest temperature at which the water is to be kept. For

ample, an apparatus to be run at a temperature of 300° F. ould, for safety, have a closed tank whose capacity is 10 per nt. of that of the heating system; for 400°, 16 per cent.; d for 500°, 25 per cent. of that of the entire apparatus.

15. The expansion tank should be fitted up in such part the building as will permit it to be accessible and in open

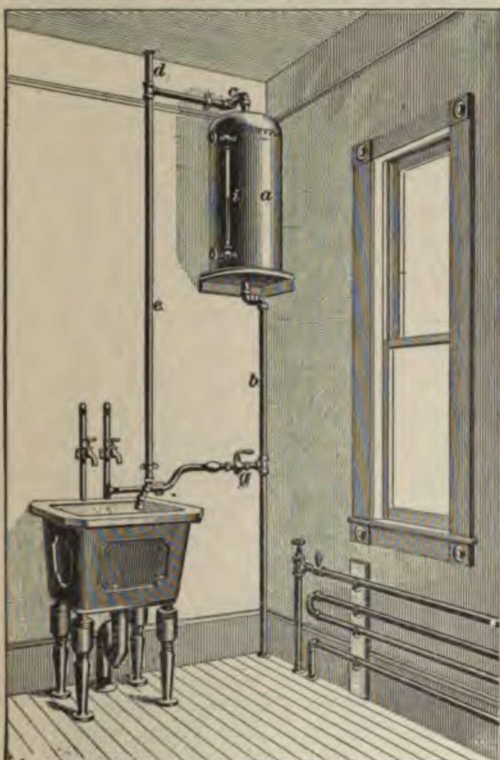


FIG. 3

ew at all times, say in the hallway of the top floor. It ıst be thoroughly protected from frost, and must be placed a point higher than the top of the highest radiator; in fact, must be the highest point of the system.

Fig. 3 shows an expansion tank *a* of the most common pe. It is set on a small shelf in the corner, and is located

above the top of the highest radiator in the building. The 1-inch pipe *b* communicates with the heater. This communication must be open at all times, no valves, cocks, checks, or any other apparatus whereby communication between the tank and the boiler may be cut off being placed on this pipe. The surface of the water in *a* is open to the atmosphere by means of the pipe *c*, which leads into two pipes *d* and *e*, the former being led to the atmosphere at some safe point, say above the roof of the building, and the pipe *e* dropped down to discharge openly over and into a slop sink. The heating system may be filled with cold water from the plumbing system, by opening the stop-cock *g*, through which the quantity of water lost by evaporation and leaks may be replenished at any time. When the system is filled with cold water, the water-line of the expansion tank should be near the lower end of the glass gauge *i*, so that when the water in the system becomes heated and consequently expands into the tank, the water-line will not be above the gauge glass. The actual size of an expansion tank, then, is that part between the gauge-cocks; of course, the space within the tank above and below the gauge-cocks serves as tank capacity, but the water-line in such space cannot be observed.

If at any time the water in the system should boil, steam and water will rise up the pipe *b*, pass through the tank, and be discharged through *c*, the water falling by gravity into the slop sink. The pipe *d* acts chiefly as a relief pipe to prevent siphonage of the tank by the long leg *e*.

16. Expansion tanks are often furnished with a ball-cock that allows water to flow into them when the water-line descends too low. The ball-cock maintains a practically uniform water level in the tank for the several temperatures; that is to say, a water-line near the top of the gauge for high temperatures, at the base of the gauge for low temperatures and water-lines between these points for intermediate temperatures. This prevents the necessity of running in a little water at intervals by the use of the stop-cock *g*, Fig. 3, to compensate for evaporation, etc.

17. It must be understood that the greatest temperature to which the water can be heated in the open-tank system is simply the boiling point at atmospheric pressure. This is a comparatively low temperature, and, in order to obtain the proper amount of heat in the building, large radiators must be employed. To obviate this, that is, to gain a higher temperature for the water, and, consequently, be able to accomplish the same amount of work with smaller radiators, a closed tank is sometimes employed. There are, however, great dangers connected with the use of the closed tank system, particularly if the tank is hermetically sealed. For example, suppose that the pipe *c* is disconnected from the tank *a* in Fig. 3, that the tapping is plugged up so as to hermetically seal the tank, and that the system is filled with cold water up to the bottom of the tank, assumed to be 30 inches deep, the tank, of course, being filled with air at atmospheric pressure. The water is heated and therefore expands into the tank. As it rises, it compresses the air and consequently the pressure is increased. When the air is compressed to half of its original volume, the pressure on the surface of the water will be equal to about 15 pounds by the gauge. When it is compressed to one-fourth of its original volume, the pressure will be doubled again, and so on, the absolute pressure increasing inversely with the volume. Thus it will be seen that a very high pressure can be produced in the closed tank, even before the temperature of the water reaches 212°.

When a pressure is produced in the tank, it is distributed uniformly throughout the entire system, the increase in pressure on every square inch of the boiler, or any other part of the system, being precisely equal to the increase of pressure in the tank. Ordinary types of boilers and radiators cannot resist a very high pressure, and when subjected to high pressure they are consequently liable to burst, the rupture taking place at their weakest point. If the temperature of the water in the system is less than 212° F., the only result of the burst or cracked plate would be the damage done to the building by water. If, however, the temperature of the

water is much higher than 212° F., the burst would blow water and steam with great violence, or perhaps the apparatus would explode in much the same manner as an ordinary steam boiler. To avoid this danger, then, and to have in the system as low a pressure as possible consistent with the temperature desired, a larger expansion tank should be employed, and a safety valve loaded to a safe working pressure should be placed on an overflow or vent pipe, such as *c*, Fig. 3.

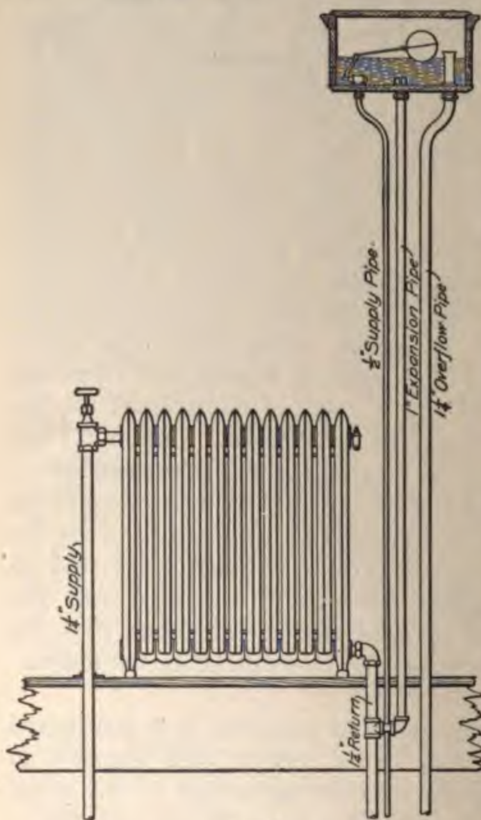


FIG. 4

18. Fig. 4 shows a frequently used method of making connections to the expansion tank, which in this illustration is of the horizontal flush-tank pattern, with automatic ball-cock feed and an overflow discharging at some convenient point below the tank. As shown, the expansion pipe is connected by an **L** and short nipple to a **T** in the return riser of one of the radiators on the top floor, thus offering no obstruction to the natural circulation of water through the radiator.

PIPING SYSTEMS

CLASSIFICATION AND COMPARISON

19. There are two systems of hot-water heating; viz., the *closed*, and the *open*, called also the *high-pressure* and the *low-pressure system*. The choice of a system for any particular building or for special service depends in each case on the local circumstances.

The **low-pressure, or open-expansion-tank, system** of warming buildings with hot water is that in which the water within the heating system is constantly open to the atmosphere. The low-pressure system operates with a maximum temperature of 210° or 212°, and the range of temperature is usually about 20°. The area of heating surface must, therefore, be quite large. The motive force is so small, that in large jobs the size of the distributing pipes and mains becomes very inconvenient. These large pipes also add greatly to the cost of the apparatus.

For ordinary dwellings, the low-pressure system has substantial advantages. It is not liable to damage by explosion or by neglect. It can be operated by any person capable of maintaining a proper fire in the boiler, and if properly erected cannot get out of order.

20. The **closed-tank, or high-pressure, system** is that in which the hot water within the heating system is not open to the atmosphere, but is enclosed in an air-tight apparatus, much the same as water is enclosed in an ordinary steam boiler.

In the high-pressure system the temperature of the water may be anything from 212° to 400°, or even more, for heating purposes. Where there is no objection to high temperatures and the accompanying risks, it may be used in preference to the low-pressure system. It requires strong boilers and radiators, the pressure at 250° being about 121 pounds per square inch by the gauge, but the apparatus is much smaller than that used for low-pressure heating. The range of

temperature at the radiators between the inlet and outlet is large, amounting sometimes to 150°, or more; consequently, the pipes used may be quite small. Usually, however, the range is about 50° or 60°, which means that the radiators also may be small. This gives a motive force about three times as great as in the low-pressure apparatus, the range in which is usually about 20°.

21. Fig. 5 is a conventional drawing that illustrates an open, or low-pressure, system, wherein *a* is the boiler, *b*, *b'* the piping, and *c* an open tank, so arranged that the

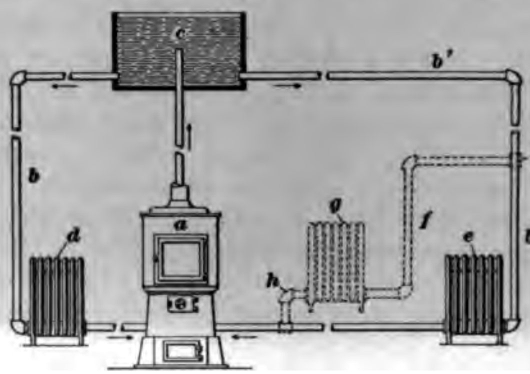


FIG. 5

heated water passes directly upwards from the boiler to the tank, and thence, flowing downwards through the distributing pipes, returns to the boiler. In this apparatus, the temperature of the water in the tank will not rise above 212° F., and consequently no pressure will be exerted in the piping, other than that due to the weight of the water. As shown, only two radiators *d* and *e* are connected with the system, but any desired number might be used. In such a system the motive force acts vertically, the heated currents of water rising directly from the boiler preferably through a riser having neither bends nor elbows, to the tank, from which the distribution of hot water takes place.

This method of arranging the apparatus cannot always be accomplished, especially where the apparatus is set up in a

building already otherwise completed, in which case it may be impossible to run the riser without elbows. When the apparatus is put in a building during its construction, it is usually easy to find a way to accomplish this end. By so doing there is never any difficulty with the circulation, provided that the piping is not clogged with foreign matter. It will be seen that each radiator has in its inflow and outflow pipes entirely separated from the rest of the piping, and communicating directly with the tank and the boiler.

The dotted lines at *f*, *g*, and *h* show an attempt to supply a radiator by a branch pipe *i*. This is a mistake that is often made in piping for hot water. Water circulating in a hot-water apparatus will seek the easiest and least obstructive paths. In Fig. 5, the radiator *e* would have a good circulation, while the radiator *g* would have a very slow circulation, if any at all, and the swifter the circulation in pipe *b'* and radiator *e* the worse it will be for radiator *g*. The reason for this is that the downward drop or flow of the water in the pipe *b'* is perfectly natural and meets with no obstruction, but at the point *i* an attempt is made to divert the flow from its natural channel. As it is not as easy for the water to flow through the pipe *f* as through the pipe *b'*, the consequence is, that when the point *i* is reached, the downward current refuses to be switched off into the pipe *f*, as it finds it easier to continue its direct downward course, and as a result the pipe *f* gets little or no heated water. It is often very perplexing to account for the want of circulation of water in pipes that are branched from the main piping. To cure this evil all sorts of expedients are sometimes resorted to; this simply emphasizes the fact that wherever it is possible to get a direct flow from the tank *c* to a radiator and then to the boiler, it is better to do so. The main objection and the only one of any force, against giving each radiator its separate inflow and outflow pipes is the extra cost of piping, but in ordinary house warming this is a very small matter compared with the difficulty of providing shunts, by-passes, and other current-destroying devices that are sometimes used. It is not intended to intimate that shunting cannot

be successfully accomplished under certain conditions, but the point sought to be made prominent is that, the motive force being so small, it is the best practice, wherever it can be carried out, to have the circulation as direct, or with as little shunting, as possible. To exemplify this, if the pipe b', Fig. 5, were doubled in diameter from the tank c to the point i, so as to contain sufficient water, the current would more easily and surely divide at that point. Part would flow through the pipe f and the radiator g, for immediately below the point i the water would meet a smaller pipe to carry it to the radiator e. It would therefore receive a check, be turned toward the pipe f, and enter it.

22. In poorly arranged systems of piping, it frequently happens that several radiators in the system receive but little hot water while others have an abundant supply. In such cases it requires better judgment and more patience to discover the cause of the trouble than to remedy it after discovery. The foundation of any such difficulty may be in the small motive force incident to all hot-water circulating devices. This being the fact, it behooves the designer never to lose sight of the small amount of force he has at command with which to accomplish the desired end.

ARRANGEMENT OF PIPING

23. Water at ordinary temperatures, if exposed to the atmosphere, is always charged with a certain amount of air and other gases that it seems to hold in solution. For example, distilled water, when exposed to the atmosphere, will absorb about 4 per cent. of its own volume of air, and if placed in an atmosphere of carbon dioxide it will absorb 100 per cent. of its own volume.

When water charged with air or other gases is increased in temperature, the gases are gradually driven off from the liquid and rise in small bubbles to the surface until the water has reached the boiling point, when all the air will be liberated and steam will form. Now it will readily be seen that when a fire is first started in a hot-water boiler, air will be

liberated from the water and will rise to the highest points of the heating apparatus, where it will accumulate and form *air locks* if it cannot escape to the atmosphere. This matter must be carefully considered in constructing hot-water heating apparatus, because the motive force is so small that it may be easily neutralized and the circulation stopped by an air lock of comparatively small size. Air always collects in all high places, such as the tops of radiators, the upper ends of vertical pipes, etc., and these points should always be provided with air vents.

24. All horizontal supply, or flow, pipes should be inclined upwards on a uniform grade, so that the air will readily flow into the risers. The air in the pipes will then pass into the expansion tank and escape into the atmosphere or into the radiators. If this cannot be done, an automatic air vent of sufficient capacity must be attached to the piping at the highest point.

In many cases, air pockets may be vented advantageously by attaching a small pipe to the top of the pocket, and extending it to the top of the house, at least as high as the top of the expansion tank, leaving it open to the atmosphere, preferably over the expansion tank. This makes a reliable vent, but the special pipe cannot always be permitted. Care must be taken to keep it from freezing, because there is no circulation through it.

25. A bubble of air lodged in a pipe will obstruct the flow of water through it, to the same extent as a block of wood or metal of the same size. Thus, in Fig. 6, if the

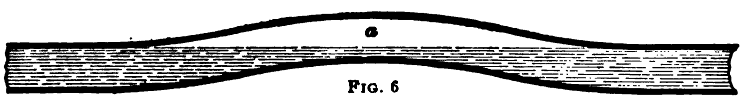


Fig. 6

bubble *a* occupies two-thirds of the area of the pipe, the remaining third only is available for the passage of water.

Although the air is very elastic and light, yet it occupies space just as positively as any solid substance. The bubble can be dislodged only by a much stronger current of water

than can usually be found in a hot-water heating apparatus. The best remedy for air lock in a pipe is to straighten the pipe. Whether the bend that holds the air is long or short, or whether it occurs in the flow or return pipes, is of little consequence, because the effect is the same in all cases.

26. A bubble or small air lock in a local circuit will, in many cases, completely stop the circulation. Thus, when several radiators are so connected to the same supply and return mains that each is on a local and practically independent circuit, the force that impels the water through them is so nearly alike in each, that the impediment caused by an air bubble lodged in one of the connections is usually sufficient to stop the flow through that circuit, and to divert all the hot water into the other circuits.

The manner of fitting up and connecting pipes for hot-water service is substantially the same as for steam heating. The expansion of the pipes by heat must be provided for by using spring pieces, etc. in the same manner.

27. All horizontal branches from the flow main are generally connected into the top of the main, or at least should be taken off by means of eccentric fittings, which will bring the top of the branch flush with, or a little above, the top of the main, so that all air bubbles may pass freely forwards and not accumulate in the main.

For the purpose of equalizing the flow of water throughout the main circuit, it is frequently found desirable to take supply-branch connections near the boiler from the side instead of the top of the flow main, thus reducing the flow of water to the radiators near the boiler and increasing the flow of water to the radiators at the extreme end of the circuit. Branch connections to the risers of radiators located on upper floors may advantageously be taken from the side of the main instead of the top, thereby retarding the flow of water to high points and improving the circulation through radiators on the lower floors.

28. In the case of indirect radiators set at a lower level than the main, the branch should always be taken from the

side of the main, as indicated in plan view in Fig. 7 (*a*) and never from the top. If the branch rises from the top and then descends to the radiator, there is thus formed a pocket

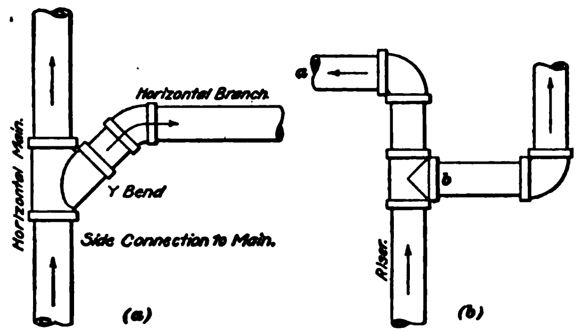


FIG. 7

in which air will inevitably collect and stop the circulation. A branch connection such as is shown in Fig. 7 (*b*) may be employed when the radiation on the line *a* is to be much favored over that on the branch *b*, as might be the case if the radiators supplied by *a* were on the first floor, while those on branch *b* were on a higher floor.

29. Occasionally it is found necessary to make an upward loop in a horizontal pipe in order to pass over a floor girder

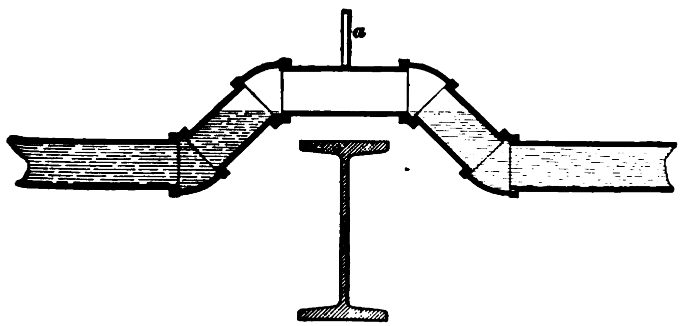


FIG. 8

or similar obstruction, as in Fig. 8. The air will collect in the upper part of the loop; therefore, a vent pipe *a* must be attached to it. As shown in the figure, the loop is

constructed with four 45° bends and three nipples; consequently, the resistance to the flow of water will be considerable. It is advisable to make the loop by bending the pipe, and to avoid the use of fittings for this purpose, where possible.

Every pipe used in hot-water heating should be smooth at the ends, and also should be reamed, for the purpose of decreasing the resistance to the flow of water through the apparatus as much as possible.

PIPING CIRCUITS

30. Simple and Compound Circuits.—A pipe circuit in which the water flows directly to a radiator through a single pipe without branches, and returns to the boiler through

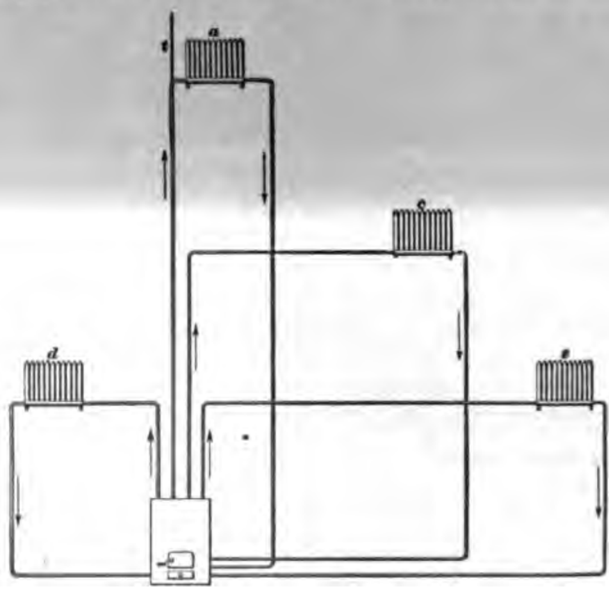


FIG. 9

another direct and special pipe, as shown in Fig. 9, is called a **simple circuit**. Although a large number of such circuits may be connected to a single boiler, each one is entirely

independent of the others, and the force of circulation is governed by the actual height of each circuit and the difference of temperatures prevailing in it.

The simple-circuit system has the advantage of positive and direct circulation in each circuit, so that the heat required at each radiator can be accurately provided for. It therefore requires less skill in designing than other systems. The system is objectionable, except for small jobs, because the number of pipes running to and from the boiler becomes so great that they are very inconvenient, and also quite expensive.

31. In a **compound circuit** the supply current moves in a main pipe of comparatively large dimensions, commonly called the *flow main*, and the return currents proceed to the boiler through a similar pipe called the *return main*. These mains are connected by a number of small branches, each of which makes a direct circuit between the flow and return mains. The radiators are connected to these branches, usually one on a branch, sometimes more.

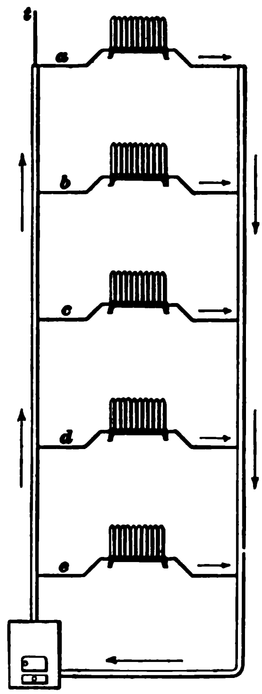


FIG. 10

Compound circuits are arranged in many different ways, most of which are variations of the two systems shown in Figs. 10 and 11. In Fig. 10, the mains are vertical, and the branches are substantially horizontal. In Fig. 11 the mains are horizontal and the radiators are attached to vertical branches or drop risers. In the former case, the effect of rapid cooling at any one radiator is to decrease the average temperature of the return main, and as all the radiators are connected to the same mains, the effect is divided and distributed over the entire system. In the latter case each radiator is

independent, and the rapidity of the circulation through it will depend on the amount of cooling that occurs at that point.

32. In Fig. 11, the radiators *e* and *d* are supplied from the same **drop riser**, and both are connected to the same return pipe. The circulation through the upper radiator will always be good, but while this continues in operation, the lower radiator is likely to fail, being unable to get any hot water. This is due to the fact that the pressure of the

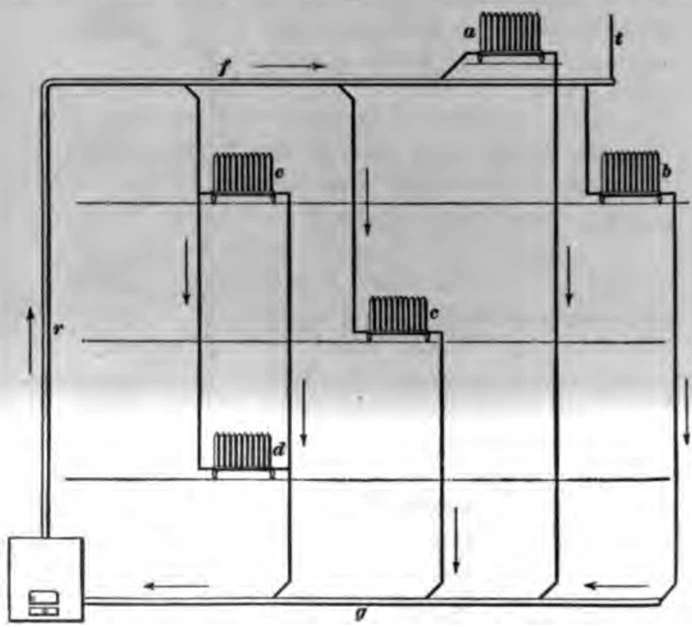


FIG. 11

cool water in the return between *e* and *d* overbalances that of the hot-water column in the flow connection to *d*, and prevents its flowing through the radiator. The trouble can be remedied, however, by providing it with a separate return connection to the main *g*, thus making it independent of the upper radiator.

33. Another method of operating a radiator on a drop riser is shown in Fig. 12. The flow connection to the supply

pipe is made at one level, and the return is connected into the same pipe at a lower level. The circulation through the radiator will depend mainly on the vertical distance between the points *d* and *e*. The flow connection may be made to the top of the radiator, as shown at *a*, or to the bottom as at *b*, as convenience may require.

34. With the arrangement indicated in Fig. 11, each radiator will be supplied with hot water of practically the same temperature, but in the case of Fig. 12, the water in the drop pipe is lowered in temperature by the cooler water returned from each radiator; consequently, the water supplied to the radiators at lower levels will be successively reduced in temperature. This will usually make it necessary to employ larger radiators on the lower floors, when this system is employed.

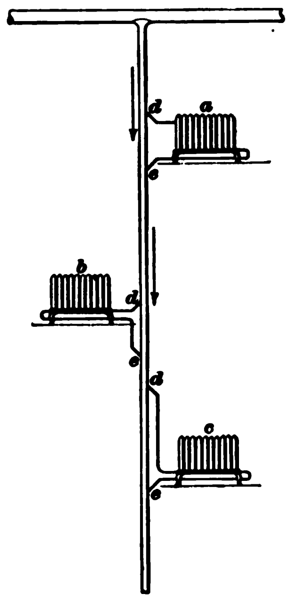


FIG. 12

35. Open and Closed Circuits.—There is quite a difference of opinion regarding the true meaning of the terms *open* and *closed circuits*. The terms and the meanings thereof, as adopted here, may seem contrary to local usage, but they coincide with the meanings of the same words as applied in the electrical profession, and therefore will help to prevent confusion or misunderstanding.

In the plans shown in Figs. 10 and 11, the flow and return mains are connected only by the radiator branches, and there is no way of maintaining a flow of water through them when the radiators are shut off. This arrangement of mains is called an **open circuit.**

When all the radiators are shut off except one or two, the amount of circulation is likely to be too small to keep the

water in the mains at a proper working temperature. Then, when the other radiators are opened for use, considerable time must elapse before the whole system heats to the

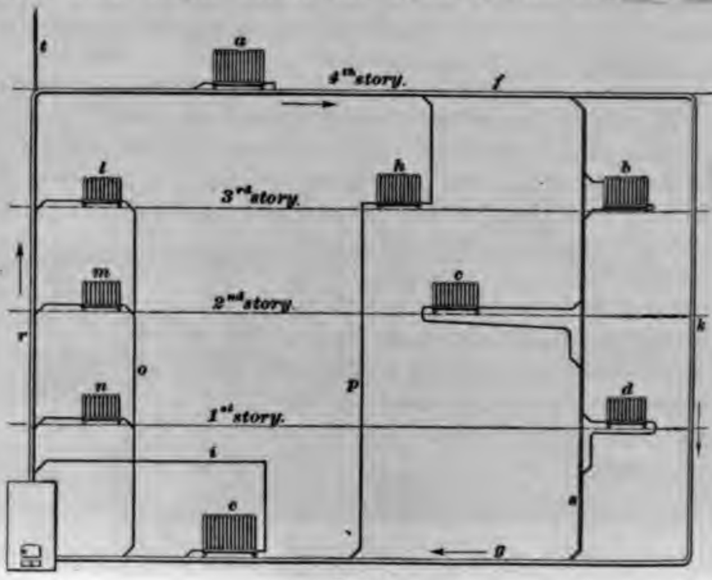


FIG. 13

desired degree. This slowness of heating may be obviated by keeping up a good circulation through the mains at all times, regardless of the radiators, by connecting the flow and return mains by a pipe k, as shown in Fig 13. This arrangement is called a **closed circuit.** The connection should be

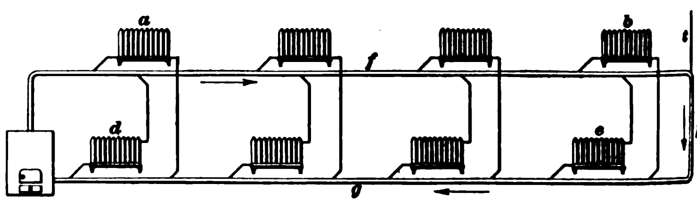


FIG. 14

as large as the extreme ends of the flow and return mains which it connects. As long as a proper fire is maintained in the boiler, an active circulation will go on in the mains,

and the water will be always at the maximum temperature, so that any or all of the radiators may be supplied promptly with hot water as soon as the valves are opened.

The closed circuit is desirable for all situations where the simple or single circuit, Fig. 9, is not used, and is adapted to high buildings as well as low ones. It is superior to all others in long, low buildings, of one or two stories, where the mains must extend a long distance horizontally, as in cases like Fig. 14.

36. Velocity of Flow in Circuits.—Unfortunately, there is no simple rule or formula by which to calculate the actual velocity with which hot water moves through a heating system under varying conditions. The conditions that affect the circulation are so changeable, scarcely two jobs being alike, that accurate coefficients of friction and other resistances cannot be obtained; consequently, the theoretical velocity—that is, the velocity that the water would have if it encountered no resistance while passing through the pipes—will be considered.

The theoretical velocity of water flowing only under the action of gravity can be found as follows:

Rule.—*Multiply 8.02 by the square root of the height, in feet, through which the water falls; the product will be the theoretical velocity, in feet per second.*

Or, $$V = 8.02\sqrt{h}$$
where V = velocity, in feet per second;
h = height, in feet, through which the water falls.

The theoretical velocity given by this rule cannot be obtained in practice, because of existing resistances.

EXAMPLE.—What is the theoretical velocity with which water will flow through a circuit whose vertical height is 25 feet, if the temperature of the flow pipe is 200° F., and the return pipe 180° F.?

SOLUTION.—Referring to Table I, the comparative volumes are seen to be 1.03889 and 1.031, respectively. Applying the rule in Art. 2, the motive column is $25 \times (1.03889 - 1.031) = .197$ ft. high. Applying the rule in Art. 36,

$$V = 8.02\sqrt{.197} = 3.559 \text{ ft. per sec.} \quad \text{Ans.}$$

37. The motive force and volume being constant, the velocity of the flow through a circuit will be inversely proportional to the sectional areas of the pipes, that is, to the squares of the diameters.

In a single circuit having flow and return pipes of equal diameters, the velocity will be the same in both. Water is practically incompressible; therefore, it must move simultaneously and equally in all parts of the circuit.

In a compound circuit the water is at liberty to move by several routes, and it always goes by the one that offers the least resistance. If several of the branch circuits are open at the same time, and the resistance is alike in each, the water will flow equally through all of them, and the velocity will be reduced in inverse proportion to the number of pipes. But if the resistance varies in the several circuits, the main part of the flow will go through the pipes having low resistance, and the circulation will be slower in the others.

In closed circuits, the flow of the water through the branch circuits is assisted by the momentum of the current that is kept moving through the mains, provided that the connections are made in a proper manner.

The actual velocity of the water in any given part of a compound circuit is difficult to compute, because of the number of variable influences that affect it. It is necessary to take into account the difference in temperature, the height of the returns, the resistance of the pipes, and the proportion of the total current that is passing through other circuits. Some of the factors entering the problem cannot be determined with any degree of accuracy; hence, the results of a definite rule are liable to be so misleading as to render it inadvisable to give a rule for actual velocity of flow in circuits.

38. Resistances to Flow.—The first resistance encountered by water entering a pipe of the ordinary form, or when passing through the ordinary orifice, is the *vena contracta*, or, as it is more frequently called, contracted vein, an example of which is shown in Fig. 15. A flow pipe *a* is screwed into the top *b* of an ordinary cast-iron water heater. The hot

water flows in the direction of the arrows from the heater to the radiators. On entering the pipe *a* the water contracts in sectional area just inside the orifice, as shown at *c*, the amount of contraction depending on the velocity with which the water enters *a* and the nature of the orifice. Under ordinary conditions, if the orifice has sharp edges, it is estimated that the actual diameter at *c* is about .9 that of the pipe. This, then, reduces the theoretical volume of water that the pipe would pass about 20 per cent.

The contracted vein not only occurs at the connections to the heater, but actually is present to a greater or less extent in all the fittings and valves commonly employed in a heating apparatus.

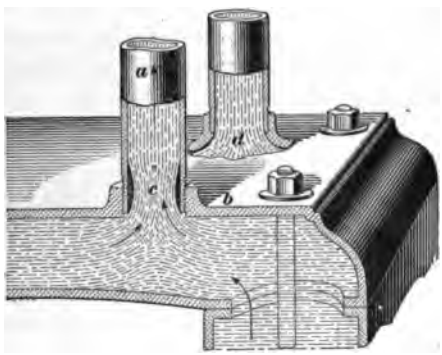


FIG. 15

The evil effects of the contracted vein can be obviated by giving the orifice a funnel-mouthed shape; such, for example, as shown at *d* in Fig. 15. To prevent the contracted vein in fittings, so far as practice will allow, the pipe ends should be reamed out to a beveled edge before being screwed into the fittings. The proper shape of reamer for such work is that of a cone whose height is twice the diameter of the base. Burrs formed in the pipe ends when the pipe is cut by the common wheel cutters should in all cases be reamed out, as they offer much resistance to the flow of the water in a heating apparatus.

The frictional resistance to the flow of water through pipes varies directly as the length of the pipe, inversely as the area of the pipe, and very nearly as the square of the velocity. All three of these things must be considered in determining the proper diameter to be given to the various pipes composing the apparatus.

39. A form of resistance that should carefully be considered when laying out the different lines of a hot-water heating apparatus, is that due to change of direction of the flow.

When water or any other matter is moving in a straight line, it will continue to move in that direction until it encounters a force that will either bring it to rest or change its direction. If the moving body is brought to rest, the force encountered is equal and opposite to that of the moving body. If, however, the moving body is simply deflected or changed in direction, only a part of the force or energy of the moving body is utilized to overcome the resistance. This is precisely what takes place when water flows through elbows, **T**s, and other fittings—a portion of the effective head or motive column is lost at every point where there is a change in direction of the flow of water.

The resistance caused by elbows, **T**s, and other fittings, is considerable. The resistance in a bend made with a common elbow, the ends of the pipes being left square, is about equal to the frictional resistance of a piece of straight pipe having a length equal to 100 times its diameter. If the ends of the pipes are beveled inside to an edge, the resistance may be reduced to seventy diameters, or even to sixty in small sizes. With a long bend having a radius of five diameters, the resistance falls to ten diameters, or less.

A plain **T** offers about the same resistance as an elbow, and a return bend from $1\frac{1}{2}$ to 2 times as much. The gain made by reaming the ends of the pipe is much less in the large diameters than in the small sizes.

The loss of head varies considerably with the nature of the fitting. If the turn is short and abrupt, such as in an ordinary sharp elbow, a greater loss of head will take place than would occur in easy sweeping bends. To reduce this loss of head to a minimum, special fittings are made for hot-water heating apparatus, and they should be used on all work where the motive column is small compared with the length and diameter of the pipe.

ONE-PIPE, OR SINGLE-MAIN, SYSTEMS

40. A certain system of piping for hot-water heating is commonly called the **one-pipe system,** but the name is a misnomer. While it is practicable to operate a steam-heating system with a single main, and with single connections to the radiators, it is wholly impracticable to do so with hot water. Hot-water radiators must have two connections. The overhead system represents the nearest approach that can be made to a one-pipe system of hot-water distribution, the flow branches and return branches of the radiators being connected to the same drip riser, as in Fig. 12, or radiator

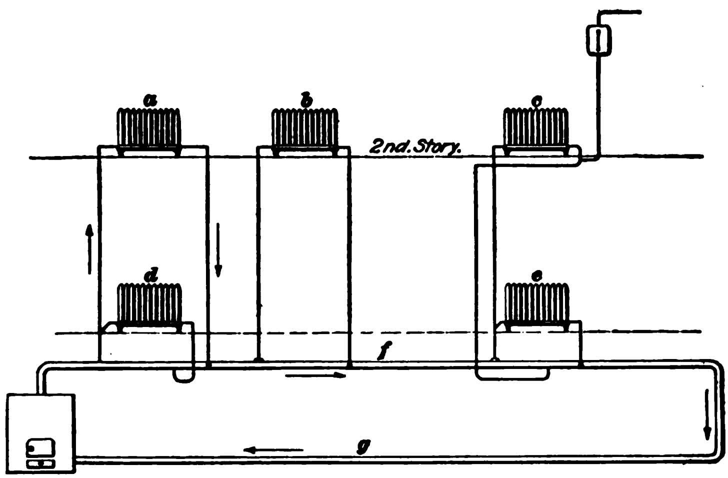


FIG. 16

branch connections may be made to the same main substantially as shown in Fig. 16. In the latter system, the main is of unusually large diameter, so that it acts as a reservoir, and the movement of the current through it is comparatively slow. The risers are tapped into the top of the main, and the returns are connected into the side or bottom, so that they deliver the cooled water into the lower part of the main.

It is necessary that the temperature of the water be maintained at a proper degree throughout the whole length of

the main, so that the water supplied to the radiators farthest from the boiler will be reasonably hot; otherwise, the radiators supplied with the cooler water must be made very large, in order to compensate for the low temperature of the supply.

The main in a one-pipe system is usually carried around the basement walls exactly as for steam heating. It is connected to the boiler by a return pipe *g*, thus making a closed circuit and insuring a circulation through it at all times. In stores and office buildings where there are a large number of radiators on a single-main circuit, each being controlled by a different person, the advantage of having the circuit closed is of great importance. This system has no apparent advantages, except that in some cases it is cheaper to install. The circulation in each radiator depends solely on the actual height of its individual return column, and the system as a whole is sluggish in operation.

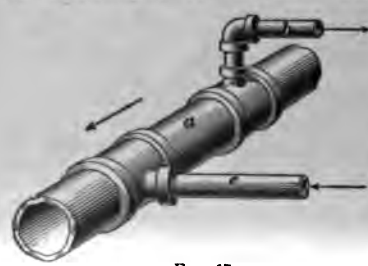


FIG. 17

41. In the one-pipe system, the connections for a radiator are made substantially as shown in Fig. 17, the main current moving through *a* in the direction of the arrow, *b* being the flow connection and *c* the return. The object here is chiefly to take the supply of hot water from the top of the main and return the cooler water into the bottom.

42. One of the disadvantages of the single-main, or continuous-circuit, system of hot-water heating is that the lack of a uniform temperature throughout the circuit necessitates proportioning the radiators so as to provide for differences in heating power at different points in the main, which should be arranged so as to secure the advantages of a divided instead of a continuous circuit.

43. Whenever it is possible to do so, it is an advantage to install the single-main system with multiple, or split,

circuits, as indicated by a plan view in Fig. 18, which shows the piping system for a small one-story library. This not only permits the use of smaller piping but reduces the temperature drop, thereby insuring greater uniformity of temperature throughout the whole building. Supply and return connections may be taken from special fittings, thus reducing the expense of installation as compared with systems

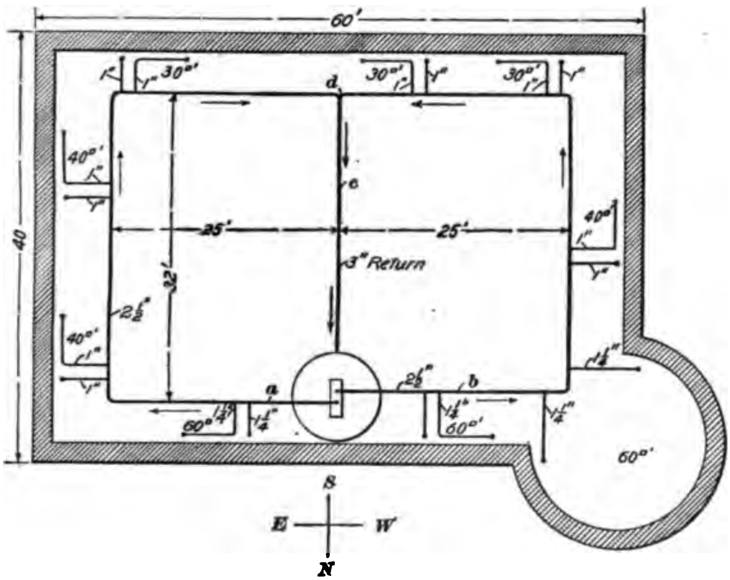


FIG. 18

wherein the connections are made as shown in Fig. 17. In arranging the mains as shown in Fig. 18, the highest points are at the riser connections nearest the boiler. The separate main pipes *a* and *b* run in opposite directions around the cellar, to be connected into the return *c* by means of a long-turn twin elbow at *d*, where the main drops to or below the cellar floor and thence is carried to the boiler.

44. In the **overhead system** of hot-water heating, shown in Fig. 19, a single main riser *a* is carried directly upwards from the boiler to the attic, proper provision being

made for expansion; the riser usually supplies two opposite branches *b*, *b* of smaller diameter, as shown. When the

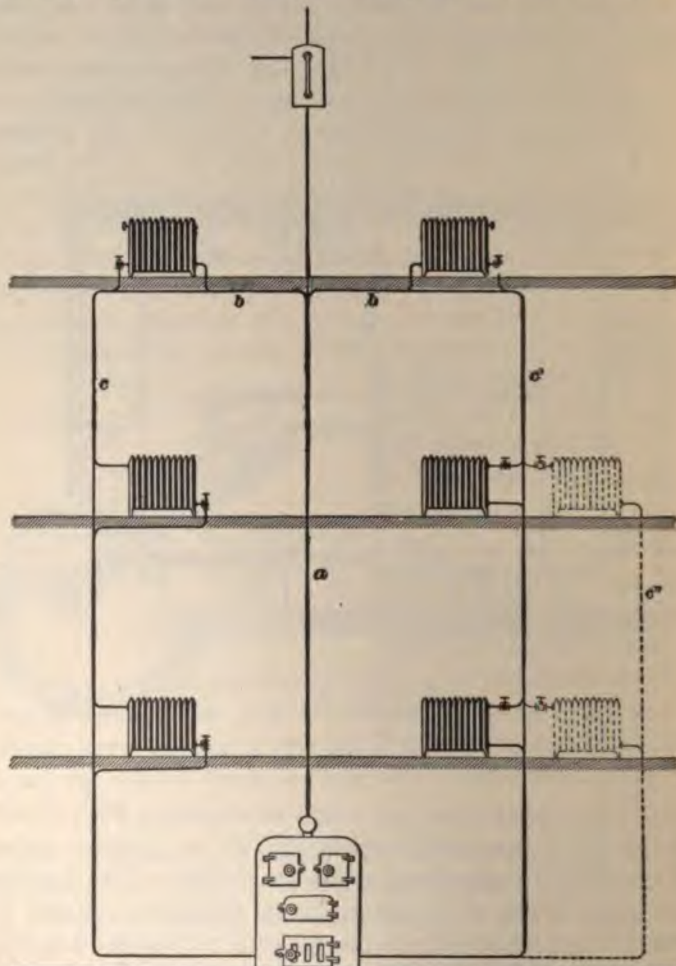


FIG. 19

piping can be so arranged, it may be run beneath the top floor, as shown, with the top-floor radiator connections taken from the branch mains, as indicated in Fig. 20, the radiator valves

being placed in the return connections. From the branch mains *b*, connections are taken for the drop risers *c*, *c'* that supply the radiators on the floors below. Connections between the drop riser and radiators may be made as shown at the left of Figs. 19 and 20, with the radiator valve in the return connection, or as shown at the right, with the radiator valve in the supply connection. In some cases two drop risers, as *c'* and *c''*, Fig. 19, are used for each line of radiators, this case being also shown in Fig. 11, the supply riser being reduced in size at each radiator connection, and the size of the return riser being correspondingly increased.

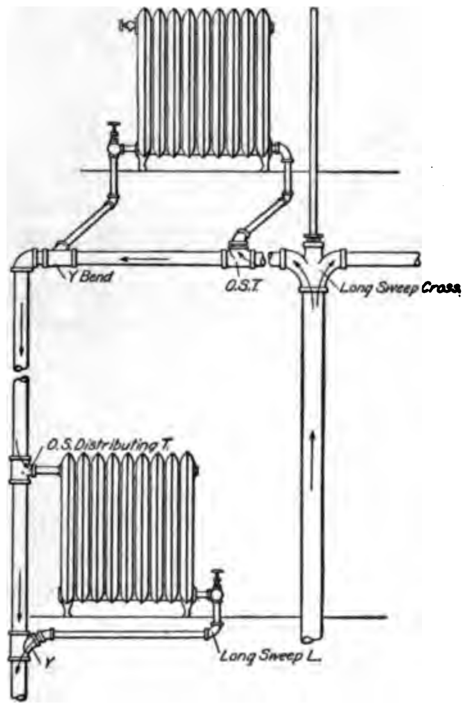


Fig. 20

45. With the overhead, or drop, system of hot-water heating no air valves are necessary, except when the system is arranged as shown in Figs. 19 and 20, when the radiators on the top floor should be equipped with air valves for venting the air that would escape through the expansion tank if all the radiators were served by drop risers. One of the advantages of the overhead system of distribution is that it provides no opportunity for one radiator to rob another of its supply of hot water, but all radiators work together harmoniously, so to speak. The water that passes through one radiator must flow through the one below it whenever

the radiator valve is open. To preserve the greatest possible difference in temperature between the ascending and descending columns of water, the riser main and the horizontal mains taken therefrom to supply the drop risers should always be well covered with some good pipe covering, but the drop risers should not be covered.

46. Expansion tank connections may be made by running a 1-inch pipe from a bushing in the long-turn cross at the top of *a* in Fig. 19, or the expansion pipe may be attached to the return end of one of the radiators on the top floor, in case such an arrangement would be more convenient. The overhead system is well adapted for use in large residences where the heating of the first floor is accomplished by means of indirect radiation, the amount of which should be 50 per cent. in excess of the amount of direct radiation that would be required to heat the first-floor rooms.

TWO-PIPE SYSTEMS

47. An illustration of the **two-pipe system** of hot-water heating is presented in Fig. 21. The hot water flows from the boiler through the supply mains and risers a, a' to the radiators r, r, from whence it returns to the boiler through the risers c', c' and return mains c, c. Both flow and return mains pitch upwards from the boiler, as shown. Provision for expansion of the water is provided by the expansion tank o, which is connected with one of the return mains near the boiler, as indicated.

48. The two-pipe system shown in perspective in Fig. 22 is sometimes called the **parallel system,** because the flow and return pipes are run throughout the building substantially parallel to each other. In this illustration, the flow pipes are shown by solid lines and the return pipes by dotted lines. The boiler is located in the cellar, as usual. From the two tappings on the upper header are run the flow mains a and b. The main a is split into two mains c and d by a twin elbow. The return mains are all run on the same

horizontal plane and parallel with their respective flow mains, except the return main *e*, which is run under the main *a* so that a twin elbow and 45° offset can be used at the point *f* to raise the mains *g* and *h* to the horizontal planes of the mains *c* and *d*. The branches to the risers and the first-floor radiators are taken off midway between the top and the side

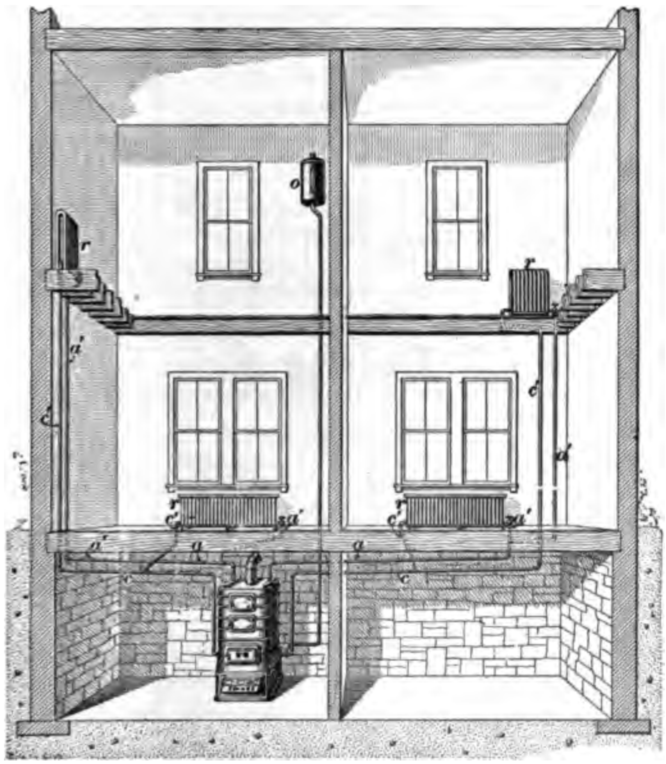


FIG. 21

of the flow and return mains, by the use of a reducing **T**, a short nipple, and a 45° elbow at each branch. The radiators *i*, *i* are supposed to be located on the first floor and circulation to them has been favored by making their connections directly to the main or taking them from the top of the riser connections at the cellar ceiling. The radiators *j*, *j* are

located on the second floor, *k*, *k*, on the third floor, and *l*, *l*, on the fourth floor. Gate valves are shown located in the mains *g*, *c* to shut off that circuit; gate valves are also located

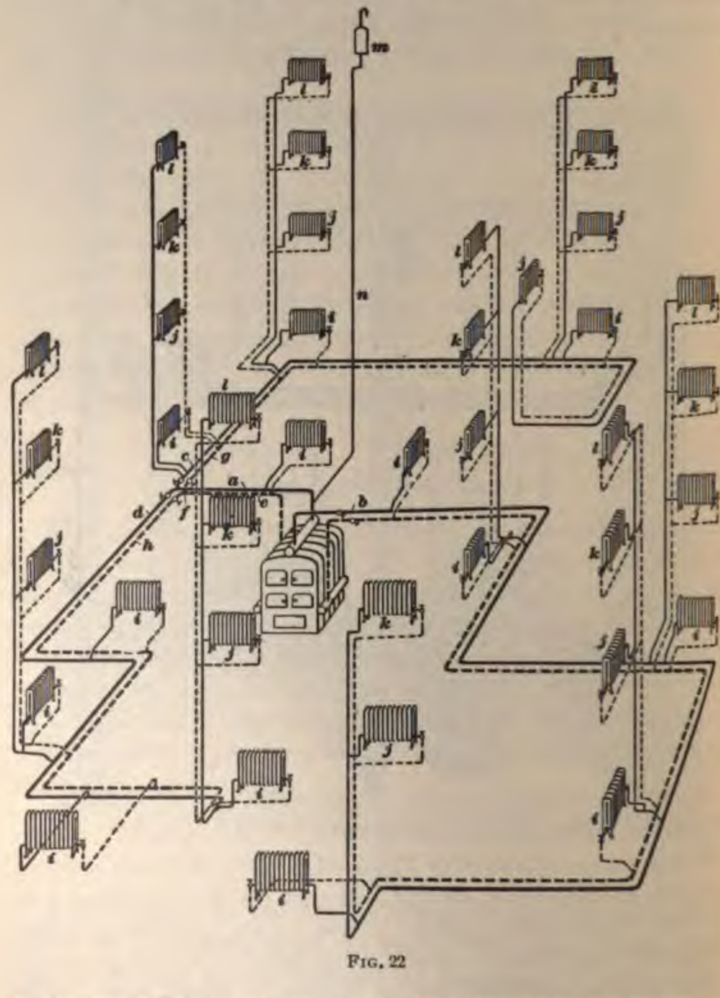


FIG. 22

in the mains *d*, *h*, and on *b* and its corresponding return to shut off these circuits. The expansion tank *m* is provided with a pipe continued up through the roof and bent over in

the form of a return bend. The bottom of the expansion tank is connected to the vertical part of the flow main *a*, directly over the boiler. Many fitters connect the expansion pipe to the return manifold. The advantage of connecting the expansion pipe as shown is this: If the gate valves on the mains are closed for repairs and the fire is not properly drawn from the heater, steam generated in the heater will pass up through the expansion pipe *n*, through the tank *m*, and escape above the roof without emptying the heater. If the pipe is connected to the bottom of the heater, and if the same condition occurred, the water in the heater would be pushed up through the expansion tank by the pressure of the steam generated in the heater. The parallel system of piping is very neat when properly installed and hence is favored by heating engineers. Both the flow and the return mains are graded upwards from the heater to the risers, and each radiator is equipped with an automatic air vent. Each radiator is also provided with a valve on the flow or return connection to regulate the current. In some cases gate valves are also placed on each riser connection, so that each riser can be shut off separately without interfering with the main circuits. If work is laid out as shown in this illustration and the piping is properly proportioned and the first-floor radiators favored at their connections, a practically uniform circulation and an even temperature at the radiators can be obtained.

49. It frequently happens that radiators that are located close to the risers and have a free return circulation will take more than their proper share of hot water. This not only diminishes the supply for the more distant radiators, but the water thus passed through is discharged into the return main much hotter than it should be, and the motive force of the system is impaired thereby. To remedy this trouble, the system shown in Fig. 23, and known as the **equalized system**, is sometimes employed. Its distinguishing feature is that the water is compelled to travel exactly the same distance in going to and from any radiator on a given floor. Thus, a radiator situated close to the boiler will have but

little advantage over one situated a long distance away, on the same level.

The flow main is shown divided into two sections *e* and *f* that extend around the basement walls to the point *b*, where they unite. A return connection is made to the boiler by means of the pipe *c*, thus making a closed circuit. The return mains, however, run in the opposite direction to that usually employed. They begin at the radiators nearest to the boiler, instead of the most remote, as in the common way. Thus, they begin at the radiators *g* and run parallel with the flow mains until they finally unite in the pipe *d*. It

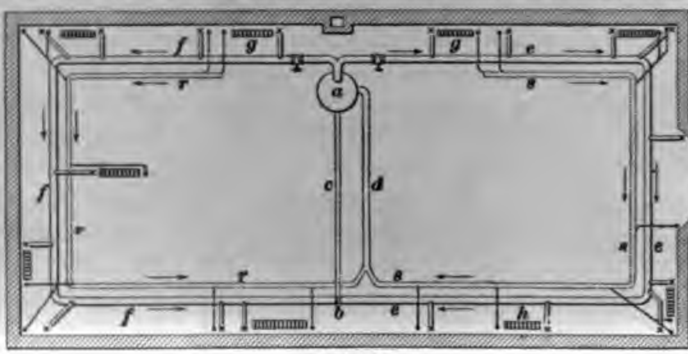


FIG. 23

will be seen that the water passing to the radiator *g* runs only a short distance in the flow main; but, since it is obliged to pass through the whole length of the return circuit, the aggregate distance traveled by the water in going to and from the radiator *h* is precisely the same. Thus, the frictional resistance to the flow of water to all of the various radiators on the same floor is practically equalized if the pipes are properly proportioned.

HOT-WATER HEATING WITH BOILER AND RADIATION ON SAME FLOOR

50. One of the problems frequently presented to the hot-water fitter for solution is that of arranging a hot-water heating apparatus so as to obtain satisfactory results in heating when the boiler and radiation are located on the same

floor. Figs. 24 and 25 are, respectively, the plan of a lodge room and an elevation of the piping therefor, the boiler and radiating surface being practically on the same level.

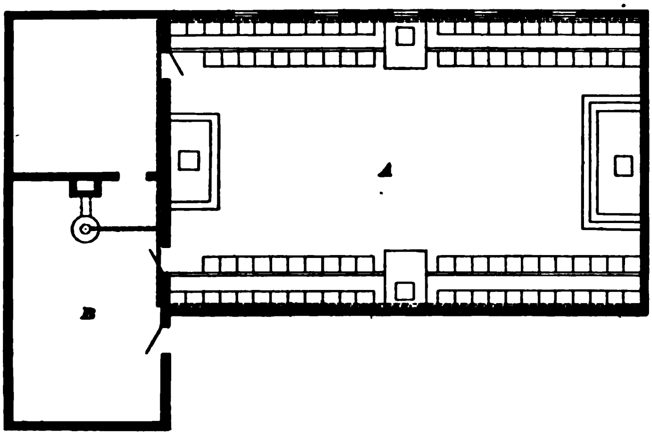


FIG. 24

In order to prevent marring the general appearance of the lodge room *A*, Fig. 24, the heater *a*, Fig. 25, was placed in the room *B*, being connected to the chimney by a galvanized sheet-iron smoke pipe *b* furnished with a damper. A 2½-inch

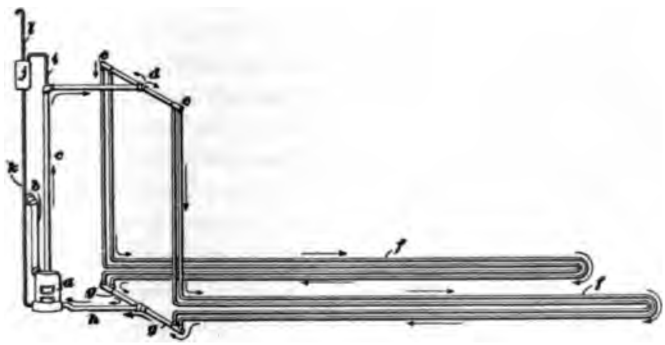


FIG. 25

flow pipe *c*, Fig. 25, extends vertically upwards into the space over the room *B*, Fig. 24, as far as possible. The flow main branches at *d* with a 2½″ × 2″ × 2″ twin elbow into

two 2-inch mains, which in turn branch out into two 1½-inch drop risers at *e*, *e*. These risers drop into the anteroom, then turn along the side walls of the lodge room as at *f*, *f*, and return as shown, thus forming a continuous wall coil just above the side platforms. The return ends of the coils join the heater by 2-inch pipes *g*, *g*, and by a 2½-inch pipe *h* laid under the anteroom floor. A circuit is thus formed and the hot water will flow in the direction of the arrows. The object in raising the flow pipe so high is to obtain power to cause the water to circulate rapidly enough to have a suitable temperature in the pipes *f*, *f*. As the velocity of circulation depends on the difference between the density of the water in the ascending and descending vertical pipes, the height of these pipes above the heater, and the resistance to the flow by friction, etc., it is evident that the higher the flow main is carried, the colder the descending lines are; and the fewer the elbows and the larger the pipes, the more rapid will be the circulation, so that more heat will be conveyed from the heater to the lodge room by the water in a given time. A ¾-inch or 1-inch pipe *i* should be taken from the highest point of the flow main to prevent air locks. In case of steam rising in *c*, the pipe *i* will deliver into the top of the expansion tank *j*, which is placed where its glass water gauge can be seen. The expansion tank should be fed from the plumbing system either by hand or automatically. The bottom of *j* connects to the bottom of the heater by a 1-inch pipe *k*. There is no danger of blowing water out of the system by this arrangement, because the steam generated in *a* will rise and deliver through *i* into *j*, and any water that may be carried along with it will fall into *j*, while the steam escapes to the atmosphere through the outlet or vent pipe *l*. When steam passes through *c*, circulation through *f*, *f* will be increased, because of the greater difference between the mean density of the fluid in the ascending and descending pipes.

STARTING AND TESTING

51. In making a test of hot-water heating apparatus, it is necessary that the whole apparatus be tested together. It cannot be done in sections, as in steam heating, because the main question to be settled is whether the water will circulate properly at every radiator when the entire system is in use. If the system is divided into several sections that are designed to be operated independently when others are shut down, separate tests should afterwards be made of each section when working alone. It may be found that while the different sections work properly alone, they will interfere somewhat when all are operated together; some circuits will take more than their proper share of the water and will thus rob the other circuits. This trouble can usually be remedied by bushing or reducing the return connection slightly, where it joins the main, or where it enters the boiler, if the return is an independent one.

Before starting a test, every radiator should be supplied with an air vent, and every place in the piping that might accumulate air should be thoroughly vented. Care should be taken to see that every radiator valve, and every valve in the piping, if there is any, is wide open. Having attended to these preliminaries, the apparatus may be filled with water, which should be introduced at the bottom, and rise gradually, driving the air before it. Every air vent, etc. should be opened until water flows out. Fresh water always contains a considerable percentage of air or gas in solution, and as soon as the water becomes heated the gases are liberated in bubbles. If the apparatus is properly vented, there will be no difficulty in getting rid of this air, but it must be discharged from the pipes without fail, or there will be trouble.

After the apparatus has been run with a full fire long enough to become thoroughly heated, the circulation may be tested. The only convenient method of doing this is to apply thermometers at every point where it is desired to note the fall of temperature. An excessive fall of temperature

denotes that the flow is insufficient, and a small fall shows that more water is received than is required.

If the heating system is of the closed type, the safety valve should be adjusted to open at the right pressure.

PROPORTIONING HOT-WATER SYSTEMS

GENERAL CONSIDERATIONS

52. Equalization of Flow of Water.—The principal object to be sought in designing a system of hot-water piping is to adjust and equalize the resistance in each circuit and branch so that the hot water will flow with equal readiness to each radiator. This is accomplished by making the diameter of each pipe just sufficient to pass the desired amount of water under the head, or driving force, available in that particular part of the system. Artificial resistances are also introduced at some points by putting in extra elbows or bends; valves are sometimes used for the same purpose.

An ordinary low-pressure system requires larger pipes than a high-pressure system, because the difference in temperature of the flow and return is less, and the driving force is consequently smaller.

53. Temperature Drop.—The water must fall in temperature while passing through the radiator in order to emit heat. The rate of emission per hour being the same, the fall of temperature will be inversely proportional to the quantity of hot water passing through. Thus, if the temperature falls 10° with a supply of 100 cubic feet per hour, it will fall 20° if the supply is reduced to 50 cubic feet per hour. It should be noted that the temperature multiplied by the volume of the flow, or its velocity, will be a constant figure. Therefore, it is necessary to determine in advance what the fall of temperature shall be at each radiator, before the quantity of water to be supplied, or the size of the pipe required to supply it properly, can be computed.

The fall of temperature commonly allowed in good practice is 20°, while 35° is regarded as the limit in any case. For general purposes, it is assumed that the water will cool 20° in passing through the radiators, and will thus emit 20 heat units per pound or 166 units per United States gallon of 231 cubic inches.

54. Length of Circuit.—In estimating the length of any given circuit, for purposes of computation, an addition should be made to the measured, or actual, length sufficient to equal in resistance the total resistance offered by the fittings. For example, in a circuit having an actual length of 300 feet, there are eight elbows and twelve T's. Allowing 70 nominal diameters for each elbow and T, the length to be added to the actual length of circuit to represent the resistance of the fittings is $8 + 12 \times 70 = 1{,}400$ times the nominal diameter of the pipe. In the case of a 4-inch pipe this equals $\frac{1{,}400 \times 4}{12} = 467$ feet, making the estimated length $300 + 467 = 767$ feet.

The *actual length of a circuit* is always understood to be the actual distance traveled by the water in going from and returning to the boiler, or the connection at the main.

When the water flows through pipe coils, the actual distance traveled must be ascertained and included in the estimate of length of the circuit, and full allowance must be made for each return bend. It is found by experience that the ordinary flow and return connections from a radiator to the risers or mains, which have an aggregate length of about 10 feet, and include six ordinary elbows or their equivalents, will present about the same resistance to the flow of water as a plain, straight pipe from 50 to 100 feet long. Therefore, in computing the friction in a circuit, from 50 to 100 feet should be added to the actual length for each ordinary radiator connection.

55. Height of Circuit.—The horizontal pipes on the upper floors of a building, and also the risers leading thereto, may be made smaller in diameter than those on the lower

floors, because the driving force that impels the water increases with the height of the circuit, as previously explained. The proper size of a pipe having been determined for a given service on the first floor, the diameter for equal service on higher floors, the temperatures remaining the same, may be found by multiplying by the following factors:

	Second Story	Third Story	Fourth Story	Fifth Story
Factors . .	.87	.8	.76	.73

No factors are given for heights above the fifth floor, or about 50 feet, because the decrease for the succeeding stories is so small that it is of little practical account.

The area of heating surface that may be supplied by a pipe of given diameter will increase as the circuit is made higher. If the area of radiating surface known to be right for a given size of pipe on the first floor is taken as 1, the areas on the upper floors will increase in the following order:

Second Story	Third Story	Fourth Story	Fifth Story
1.41	1.72	1.98	2.24

TABLE II

HEAT EMISSION OF HOT-WATER RADIATORS

Outside Temperature Degrees Fahrenheit	Required Temperature of Radiating Surface to Maintain Rooms at 70°	Temperature Difference Between Radiating Surface and Air in Rooms	Total Heat Emitted per Square Foot of Radiating Surface per Hour	Heat Emitted per Square Foot of Surface per Hour per Degree Difference of Temperature
−10	212	142	282	2.00
0	200	130	234	1.80
10	190	120	204	1.70
20	180	110	176	1.60
30	160	90	135	1.50
40	150	80	118	1.48
50	140	70	102	1.45

56. Heat-Emissive Capacity of Hot-Water Radiation.—Owing to the fact that air circulates less rapidly over hot-water radiators because of the comparatively low temperature of the radiating surface, the heat emission per square foot of surface per degree difference of temperature is less than with steam-heated surfaces. The rate of emission varies with the temperature of the water, being approximately, in British thermal units, as given in Table II, which also gives the temperature that the radiating surface should have in order to meet the requirements imposed by varying weather conditions.

57. Radiating Surface Required.—The amount of hot-water radiation required for heating dwellings of ordinary construction when the temperature of the radiating surface is 160° F. may be found, approximately, by means of the following rule, which applies to the ordinary two-pipe system:

Rule.—*Multiply the exposed wall surface by .25 and add the actual glass surface to the product, taking the surfaces in square feet. Multiply the sum by .63 to determine the amount of direct radiation required on the first floor; for the second floor, multiply by .59; and for the third floor, by .56.*

Or, $$R = (.25\,w + g)\,c$$

where R = direct radiation, in square feet;
w = exposed wall surface, in square feet;
g = glass surface, in square feet;
c = .63 for first floor, .59 for second floor, .56 for third floor.

EXAMPLE.—How much radiation is required for a first-story, second-story, and third-story room having 268 square feet of exposed wall surface and 72 square feet of glass surface? The rooms are to be heated by the two-pipe hot-water heating system.

SOLUTION.—Applying the rule,

$R = (.25 \times 268 + 72) \times .63 = 87.57$ sq. ft. for the first-floor room. Ans.

$R = (.25 \times 268 + 72) \times .59 = 82.01$ sq. ft. for the second-floor room. Ans.

$R = (.25 \times 268 + 72) \times .56 = 77.84$ sq. ft. for the third-floor room. Ans.

58. For the single-pipe overhead system, the amount of hot-water radiation may be approximated as follows:

Rule.—*Multiply the exposed wall surface by .25 and add the actual glass surface to the product, taking the surfaces in square feet. Multiply the sum by .71 for the first floor to determine the direct radiation; by .63 for the second floor; and by .56 for the third floor.*

Or,
$$R = (.25\, w + g)\, c$$
where R = direct radiation, in square feet;
w = exposed wall surface, in square feet;
g = glass surface, in square feet;
c = .71 for first floor, .63 for second floor, .56 for third floor.

EXAMPLE.—With the overhead system of heating, how much direct radiation is required for a first-story, second-story, and third-story room having 328 square feet of exposed wall surface and 81 square feet of glass surface?

SOLUTION.—Applying the rule,

$R = (.25 \times 328 + 81) \times .71 = 115.73$ sq. ft. for the first-floor room. Ans.

$R = (.25 \times 328 + 81) \times .63 = 102.69$ sq. ft. for the second-floor room. Ans.

$R = (.25 \times 328 + 81) \times .56 = 91.28$ sq. ft. for the third-floor room. Ans.

59. Ratio of Radiating Surface to Space Heated. For ordinary dwellings having average wall and glass exposures, with the open-tank or low-pressure system of hot-water heating and direct radiation, Table III gives ratios of radiating surface to space heated such as may be employed when an approximate determination of the amount of radiating surface required is desired.

Where semidirect radiation is employed, the radiating surface should be increased at least 25 per cent.; while for indirect radiation there should be 50 per cent. more surface than would be required for heating by direct radiation. In proportioning flues for indirect hot-water heating, allow 1.5 square inches of flue area for each square foot of

TABLE III

RATIO OF DIRECT HOT-WATER RADIATING SURFACE TO SPACE HEATED

Character of Space to be Heated	Ratio of Radiating Surface to Cubic Space Heated
Living rooms, one side exposed . . .	1 to 32
Living rooms, two sides exposed . .	1 to 30
Living rooms, three sides exposed . .	1 to 28
Sleeping rooms	1 to 30–40
Hall and bathroom	1 to 20–30
Schoolrooms and offices	1 to 30–50
Factories and stores	1 to 50–70
Auditoriums and churches	1 to 80–100

radiating surface in the indirect stack for the first floor, and 1.25 square inches area for the flue to the second floor and for cold-air duct to stacks.

60. Hot-Water Boiler Ratings.—The manufacturers of hot-water boilers rate these boilers by stating the number of square feet of direct radiating surface that they will supply, all uncovered pipes being figured as direct radiation. Average practice is to base the rating on a consumption of 4 pounds of coal per square foot of grate surface per hour, assuming a heat transmission of 8,000 British thermal units per pound of coal burned to the water in the boiler, and a temperature of 170° F. at the radiator.

A careful comparison of the rating of many boilers has shown that 1 square foot of grate surface, on which 4 pounds of coal is burned per hour, is rated as capable of supplying about 206 square feet of direct radiating surface or 137 square feet of indirect radiating surface with sufficient hot water to maintain the radiating surfaces at 170° F. With these figures as a basis, Table IV has been deduced; with the aid of this table the grate surface for any hot-water boiler at various coal-consumption rates and temperatures of radiating surface

can be found; it is also possible to determine what amount of radiating surface a given boiler will be adapted for under conditions differing from those under which it was rated, and what coal consumption will be required for a given set of conditions.

TABLE IV

RELATIVE CAPACITIES OF HOT-WATER BOILERS

Temperature of Radiating Surface Degrees Fahrenheit	Factor for		Combustion Rate Pounds per Square Foot per Hour
	Direct Radiation	Indirect Radiation	
212	28.3	18.8	7.3
200	34.0	22.3	6.0
190	39.3	26.0	5.3
180	45.5	30.0	4.5
170	51.5	34.3	4.0
160	59.3	39.5	3.5
150	67.8	45.0	3.0
140	78.5	52.3	2.6

61. To find the grate surface proceed as follows:

Rule.—*Divide the radiation, in square feet, by the product of the hourly combustion rate per square foot of grate and the factor corresponding to the kind of radiation and temperature, the factor being taken from the second or third column of Table IV. The quotient will be the grate surface, in square feet.*

Or,
$$G = \frac{R}{Cf}$$

where G = grate surface, in square feet;
R = radiating surface, in square feet;
C = hourly combustion rate per square foot of grate;
f = factor taken from Table IV.

EXAMPLE.—What grate surface is required for a hot-water boiler that is to keep 1,200 square feet of direct radiation, inclusive of piping, at 140° F., with an hourly combustion rate of 4.5 pounds per square foot of grate?

SOLUTION.—By Table IV, $f = 78.5$. Applying the rule,

$$G = \frac{1,200}{4.5 \times 78.5} = 3.4 \text{ sq. ft., nearly. Ans.}$$

62. To find what radiation can be supplied by a boiler under a given set of conditions, apply the following:

Rule.—*Multiply the grate surface, in square feet, by the hourly combustion rate per square foot of grate, and by the factor taken from Table IV, corresponding to the temperature and kind of radiation. The product will be the radiating surface, in square feet.*

Or,

$$R = G C f$$

where the letters have the same meaning as in the formula in Art. **61.**

EXAMPLE.—What amount of indirect radiation can be supplied by a hot-water boiler having a grate surface of 5.6 square feet, when burning 3 pounds of coal per square foot of grate per hour and keeping the radiating surface at 200° F.?

SOLUTION.—By Table IV, $f = 22.3$. Applying the rule,

$$R = 5.6 \times 3 \times 22.3. = 374.6 \text{ sq. ft., nearly. Ans.}$$

63. The hourly combustion rate per square foot of grate can be approximated as follows:

Rule.—*Divide the radiation, in square feet, by the product of the grate surface, in square feet, and the factor, taken from Table IV, corresponding to the kind and temperature of radiating surface. The quotient will be the combustion rate per hour per square foot of grate.*

Or,

$$C = \frac{R}{G f}$$

where the letters have the same meaning as in the formula in Art. **61.**

EXAMPLE.—Approximately, what should be the combustion rate in a boiler having a grate 6 square feet in area and supplying 1,500 square feet of direct radiation to keep the radiating surface at 190° F.?

SOLUTION.—By Table IV, $f = 39.3$. Applying the rule,

$$C = \frac{1,500}{6 \times 39.3} = 6.3 \text{ lb., nearly. Ans.}$$

64. Size of Chimney.—The required size of chimney flues for ordinary installations of hot-water heating apparatus may be found in Table V, which gives the smallest size that should be used for a given amount of radiation. A chimney flue smaller than 8 by 10 inches should never be used.

TABLE V

CHIMNEY DIMENSIONS FOR HOT-WATER HEATING

Square Feet of Direct Radiation	Required Dimensions of Chimney Inches	Square Feet of Direct Radiation	Required Dimensions of Chimney Inches
375	8 × 10	1,350	12 × 12
450	8 × 12	1,500	12 × 12
600	8 × 12	1,800	12 × 12
750	9 × 12	2,100	12 × 14
900	9 × 12	2,400	12 × 14
1,050	10 × 12	2,700	12 × 16
1,200	10 × 12	3,000	12 × 16

EXAMPLES FOR PRACTICE

1. Suppose that a pipe of a certain diameter will supply 194 square feet of radiation on the first floor; how many square feet of radiation will the same size of pipe supply on the fifth floor?

Ans. 435 sq. ft., nearly

2. A first-story room having 124 square feet of exposed wall surface and 30 square feet of glass surface is to be heated by a two-pipe system of hot-water heating; how much direct radiation is required for the room?

Ans. 38 sq. ft., nearly

3. Suppose that the room in example 2 is to be heated by the one-pipe overhead system; how much direct radiation will be required?

Ans. 43 sq. ft., nearly

4. If 600 square feet of direct radiation, inclusive of piping, is to be kept at 150° F., what grate surface should the boiler have for the usual combustion rate of 4 pounds of coal per square foot of grate per hour?

Ans. 2.2 sq. ft., nearly

5. A hot-water boiler has a grate surface of 3.2 sq. ft. Burning 4 pounds of coal per hour, how many square feet of direct radiation can be kept: (*a*) at 140° F.? (*b*) at 170° F.? (*c*) at 200° F.?

Ans. { (*a*) 1,005 sq. ft.
(*b*) 659 sq. ft.
(*c*) 435 sq. ft.

SIZE OF PIPES

65. Mains.—Tables VI and VII show the area of radiating surface, in square feet, that may be supplied with hot water by two-pipe mains of a given size and of uniform diameter throughout their whole length, the radiators being located on the first floor. For higher floors, a larger amount of radiating surface can be supplied by mains of a given size; to find this amount, multiply the value taken from these tables by 1.41 for the second story, 1.72 for the third story, 1.98 for the fourth story, and 2.24 for the fifth story. The tables given are based on a fall of temperature of 20° F., and a height of circuit of about 10 feet.

To use Tables VI and VII, estimate the length of the circuit, and enter the column headed by the nearest length of circuit. Run down this column until the nearest radiation is found; the proper pipe size is then found on the left. When the choice lies between two sizes of pipe, it is usually better to err on the side of safety, that is, to select the larger pipe.

EXAMPLE.—What size of main is required for a two-pipe system to supply 900 square feet of indirect radiation, the circuit being 370 feet long?

SOLUTION.—Referring to Table VII, the nearest length-of-circuit column is 400 ft. Following this column down, and consulting the left-hand column, it is seen that 720 sq. ft. can be supplied by a 5-in. pipe, and 1,080 sq. ft. by a 6-in. pipe. Since 900 sq. ft. is midway between these two radiation values, either pipe can be chosen if practical considerations are not taken into account; but, since the choosing of the 5-in. pipe may result in failure of the heating system, it will be the part of wisdom to choose the 6-in. pipe in spite of its greater cost. Ans.

66. In proportioning mains for the single-main, or one-pipe, system of hot-water heating, satisfactory results on

TABLE VI

DIRECT RADIATION SUPPLIED BY TWO-PIPE HOT-WATER MAINS

Nominal Diameter of Pipe Inches	Total Estimated Length of Circuit, in Feet									
	100	200	300	400	500	600	700	800	900	1,000
	Square Feet of Radiation Supplied									
1	50									
1¼	90	64								
1½	140	98	85	70						
2	250	176	153	125	113	103	95			
2½	360	256	220	180	162	148	137	126	119	112
3	540	385	329	270	243	221	205	189	178	167
3½	750	533	458	375	338	308	285	263	248	233
4	1,000	710	610	500	450	410	380	350	330	310
4½	1,400	980	854	700	630	574	532	490	462	434
5	1,800	1,278	1,098	900	810	738	684	630	594	568
6	2,700	1,917	1,647	1,350	1,215	1,107	1,026	945	891	837
7	4,000	2,840	2,440	2,000	1,800	1,640	1,520	1,400	1,320	1,240
8	5,400	3,850	3,290	2,700	2,430	2,210	2,050	1,890	1,780	1,670
9	7,200	5,112	4,392	3,600	3,240	2,952	2,736	2,520	2,376	2,232
10	9,600	6,800	5,800	4,800	4,300	3,900	3,600	3,400	3,200	3,000

TABLE VII

INDIRECT RADIATION SUPPLIED BY TWO-PIPE HOT-WATER MAINS

Nominal Diameter of Pipe Inches	Total Estimated Length of Circuit, in Feet									
	100	200	300	400	500	600	700	800	900	1,000
	Square Feet of Radiation Supplied									
1	30									
$1\frac{1}{4}$	54	38								
$1\frac{1}{2}$	84	59	51	42						
2	150	106	92	75	68	62	57			
$2\frac{1}{2}$	230	164	141	115	104	95	88	81	76	72
3	378	270	230	189	170	155	144	132	125	117
$3\frac{1}{2}$	525	373	320	263	237	216	200	184	174	163
4	800	568	488	400	360	328	304	280	264	248
$4\frac{1}{2}$	1,120	784	683	560	504	459	426	392	370	347
5	1,440	1,022	878	720	648	590	547	504	475	454
6	2,160	1,534	1,318	1,080	972	886	821	756	713	670
7	3,200	2,272	1,952	1,600	1,440	1,312	1,216	1,120	1,056	992
8	4,428	3,157	2,698	2,214	1,993	1,812	1,681	1,550	1,460	1,369
9	6,048	4,294	3,689	3,024	2,722	2,480	2,298	2,117	1,996	1,875
10	8,256	5,848	4,988	4,128	3,698	3,354	3,096	2,924	2,752	2,580

circuits under 200 feet in length will ordinarily be obtained by making the diameter of the main, in inches, not less than .16 times the square root of the direct radiation supplied, in square feet.

EXAMPLE.—With a single-main system, what size of main is required to supply 400 square feet of radiation, the circuit being 190 feet long?

SOLUTION.—Size of main = $.16\sqrt{400} = 3.2$ in. In practice, a $3\frac{1}{2}$-in. pipe would be used. Ans.

67. For single-pipe system mains, where the circuit is longer than 200 feet, Tables VI and VII may be consulted, and the size of main there given increased one size.

EXAMPLE.—With a single-pipe system, what size of main is required for a circuit 900 feet long and supplying 600 square feet of direct radiation?

SOLUTION.—By Table VI, a 5-in. main is used. Then, by the statement in this article, use a 6-in. main. Ans.

68. Some fitters make the area of the flow mains and return mains equal to the combined area of the branches taken therefrom; this makes the mains larger than is actually necessary, as will appear on reference to Table VIII, worked up from experimental data, giving the number of branch pipes that may be supplied by mains of larger diameter. For example, the table shows that ten $1\frac{1}{2}$-inch branches may be taken from a $4\frac{1}{2}$-inch main, whereas by dividing the area of a $4\frac{1}{2}$-inch pipe by that of a $1\frac{1}{2}$-inch pipe, as would be necessary in using the above-mentioned fitters' rule-of-thumb, a $4\frac{1}{2}$-inch pipe would supply about eight $1\frac{1}{2}$-inch branches.

In consulting the table, it will be noticed that in several instances a fractional number of branch pipes is given; for instance, the table shows that 2.78 pipes $1\frac{1}{4}$ inches in nominal diameter can be supplied by one 2-inch main. This is to be construed as meaning that while two $1\frac{1}{4}$-inch pipes can be amply supplied by one 2-inch main, three $1\frac{1}{4}$-inch pipes cannot be supplied therefrom; but, as indicated by the decimal fraction, a smaller branch or branches can be added to the two $1\frac{1}{4}$-inch branches, as, for instance, one 1-inch branch, or two $\frac{3}{4}$-inch branches.

TABLE VIII

NUMBER OF BRANCH PIPES SUPPLIED BY GIVEN MAINS

Size of Main Inches	Size of Branch Pipes, Inches													
	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9
	Number of Branch Pipes													
1¼	1.8													
1½	2.8	1.55												
2	5.0	2.78	1.78											
2½	7.2	4.00	2.57	1.44										
3	10.2	6.00	3.86	2.16	1.50									
3½	15.0	8.33	5.36	3.00	2.08	1.39								
4	20.0	11.10	7.14	4.00	2.78	1.85	1.33							
4½	28.0	14.40	10.00	5.60	3.89	2.59	1.87	1.40						
5	36.0	20.00	12.80	7.20	5.00	3.33	2.40	1.80	1.29					
6	54.0	30.00	19.30	10.80	7.50	5.00	3.60	2.70	1.93	1.50				
7	80.0	44.40	28.60	16.00	11.10	7.41	5.33	4.00	2.86	2.22	1.48			
8	108.0	60.00	38.60	21.60	15.00	10.00	7.20	5.40	3.86	3.00	2.00	1.35		
9	144.0	80.00	51.40	28.80	20.00	13.30	9.60	7.20	5.14	4.00	2.66	1.80	1.33	
10	192.0	104.00	68.60	38.40	26.60	17.80	12.80	9.60	6.86	5.32	3.56	2.40	1.78	1.33

69. When the various branch pipes are all of the same size, Table VIII is applicable; when the various branches are of different sizes, however, recourse must be had to calculation to find the size of main capable of supplying these branches, using the fitters' rule-of-thumb mentioned in the preceding article. To save this calculation for the most common cases, Table IX has been prepared.

TABLE IX

RELATIVE SIZES OF MAINS AND BRANCHES

Size of Mains Inches	Sizes of Branches That Mains Will Supply
1	Two $\frac{3}{4}''$
$1\frac{1}{4}$	Two $1''$; or one $1''$ and two $\frac{3}{4}''$
$1\frac{1}{2}$	Two $1\frac{1}{4}''$; or one $1\frac{1}{4}''$ and two $1''$
2	Two $1\frac{1}{2}''$; or one $1\frac{1}{2}''$ and two $1\frac{1}{4}''$
$2\frac{1}{2}$	Two $1\frac{1}{2}''$ and one $1\frac{1}{4}''$; or one $2''$ and one $1\frac{1}{4}''$
3	One $2\frac{1}{2}''$ and one $2''$; or two $2''$ and one $1\frac{1}{2}''$
$3\frac{1}{2}$	Two $2\frac{1}{2}''$; or one $3''$ and one $2''$; or three $2''$
4	One $3\frac{1}{2}''$ and one $2\frac{1}{2}''$; or two $3''$; or four $2''$
$4\frac{1}{2}$	One $3\frac{1}{2}''$ and one $3''$; or one $4''$ and one $2\frac{1}{2}''$
5	One $4''$ and one $3''$; or one $4\frac{1}{2}''$ and one $2\frac{1}{2}''$
6	Two $4''$ and one $3''$; or four $3''$; or ten $2''$
7	One $6''$ and one $4''$; or three $4''$ and one $2''$
8	Two $6''$ and one $5''$; or five $4''$ and two $2''$

70. Risers.—Table X shows the area of direct radiator surface, in square feet, that can be properly supplied at various elevations by risers of a given diameter. The radiators are supposed to be connected by ordinary short connections having a total length of about 10 feet. Each story corresponds to a height of about 10 feet.

There is a practical limit to the vertical length of risers that can be used to advantage, especially in the smaller sizes of pipe. If a small riser is extended to a great height, the friction of flow becomes excessive, and the quantity of water

TABLE X

DIRECT RADIATION SUPPLIED BY RISERS

Diameter of Riser Inches	Floor on Which Radiation Is Located					
	1	2	3	4	5	6
$\frac{3}{4}$	18	25				
1	36	50	62	71		
$1\frac{1}{4}$	65	92	112	128	145	
$1\frac{1}{2}$	100	141	172	198	224	244
2	180	253	309	356	403	439
$2\frac{1}{2}$	260	366	447	515	582	634
3	370	521	636	732	828	902
$3\frac{1}{2}$	540	761	928	1,069	1,210	1,318
4	720	1,015	1,238	1,425	1,612	1,756

delivered will be much smaller than it would be with less height. The limits for the various diameters are about as follows:

Diameter, in inches	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Height, in feet	20	30	45	60	80

If a riser is diminished in diameter toward the top and the height of any given size of the riser exceeds that prescribed above, a larger size should be used. For instance, if the last proposed extension of the riser is $\frac{3}{4}$ inch, and the height of this proposed $\frac{3}{4}$-inch extension is over 20 feet and under 30 feet, a 1-inch pipe should be used.

71. Radiator Connections.—Table XI gives the area of radiator surface, in square feet, that is adapted to connections having the diameter given, for service on the first floor; that is, at an elevation of about 10 feet above the level of the return connection to the boiler.

If the area of heating surface exceeds the amount given, the fall of temperature will exceed 20°, and if it is less, the fall will be less correspondingly. If the connections are long or crooked, less heating surface can be operated, or a larger drop in temperature will occur.

TABLE XI

SIZES OF RADIATOR CONNECTIONS

Direct Radiation				Indirect Radiation	
First Floor		Second Floor			
Pipe Size Inches	Surface Square Feet	Pipe Size Inches	Surface Square Feet	Pipe Size Inches	Surface Square Feet
$\frac{3}{4}$	0 to 18	$\frac{3}{4}$	0 to 24	1	0 to 24
1	18 to 40	1	24 to 54	$1\frac{1}{4}$	24 to 50
$1\frac{1}{4}$	40 to 70	$1\frac{1}{4}$	54 to 94	$1\frac{1}{2}$	50 to 80
$1\frac{1}{2}$	70 to 120	$1\frac{1}{2}$	94 to 160	2	80 to 120

When the length of the circuit through the radiator connections exceeds 100 feet, allowing for friction of elbows, etc., use the next larger pipe size for circuits up to 300 feet in length, and for longer circuits use pipe two sizes larger than would be required for the ordinary, or short, radiator connections.

EXAMPLES FOR PRACTICE

1. A residence contains 600 square feet of indirect radiation; the circuit being 95 feet in length, what size of main is required?
Ans. 4 in.

2. In a single-main system having a circuit 180 feet long, what should be the size of the main if 400 square feet of direct radiation is to be supplied? Ans. $3\frac{1}{2}$ in.

3. If 300 square feet of direct radiation is located on the second floor of a residence, what size of riser is required? Ans. $2\frac{1}{2}$ in.

4. What should be the size of the connections for a 100-square foot radiator located on the first floor? Ans. $1\frac{1}{2}$ in.

EXAMPLES OF PROPORTIONING PIPING SYSTEMS

72. Proportioning an Open-Circuit System.—The manner of determining the proper sizes of the various parts of a hot-water pipe system by means of the foregoing tables

.1 be explained by the aid of Fig. 26. This is a diagram ›wing the area of heating surface required at each radiator, : height of the various risers, and the length of the hori- ıtal branches and mains. The vertical lines represent ers, the horizontal lines represent mains, and the oblique es indicate horizontal branches extending at right angles m the pipes to which they are attached. The horizontal tted lines indicate the several floor levels. The figures ring the symbol □ attached to them indicate the area, in

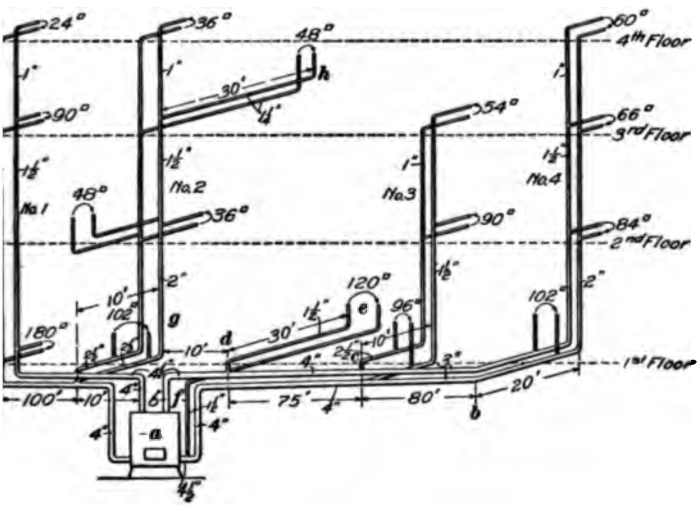


FIG. 26

ıare feet, of the radiator at that branch. The risers are nbered *No. 1*, *No. 2*, etc. for convenience in reference. e length of each horizontal branch is noted in feet, and the gths of the several parts of the mains are also noted.

Iaving a suitable working drawing, the work of computing diameters of pipes should begin at the point most remote m the boiler, which, in this case, is the radiator on the ırth floor on riser *No. 4*.

Γhe riser must supply water sufficient for 60 square feet of ıting surface at that point. Referring to Table X, it is n that a 1-inch pipe will serve 71 square feet on the fourth

floor, which size of pipe may be used if the radiator connections are short and straight.

The pipe leading from the second to the third floor must supply the 60-foot radiator on the fourth floor and also the 66-foot radiator on the third floor—a total of 126 square feet. Table X shows that a 1½-inch pipe should be used for the third floor, because the next smaller size of pipe is a trifle too small.

The riser from the main to the second floor must supply three radiators, aggregating 210 square feet. Table X shows that 2-inch pipe is the size required.

The sizes of the other risers are determined in a similar manner. The horizontal lines may then be considered. That portion of the mains extending from *No. 4* riser to the connections to *No. 3* must supply a first-story radiator in addition to *No. 4* riser, aggregating 312 square feet. The length of the flow pipe is 100 feet, which, added to the same length of return pipe, makes a circuit of 200 feet. Referring to Table VI, it appears that 312 square feet of surface, on a 200-foot circuit, requires a 3-inch pipe. This size is a little larger than that actually required, and will compensate for the elbows at *b*.

At the point *c* another circuit is attached, *No. 3*, which supplies 240 square feet of heating surface, making the total surface to be supplied at that point $240 + 312 = 552$ square feet. The distance between the points *c* and *d* is 75 feet, making the circuit 150 feet long. Table VI indicates that 552 square feet of surface, on a 200-foot circuit, requires a 4-inch pipe. The return may be continued to the boiler with that size, but the flow main should be enlarged to 4½ inches at *d* to provide for the radiator at *e*. Although the length of the connections to this radiator is much greater than is ordinarily found in practice, the radiator is comparatively close to the boiler and the branch connection is taken from the top of the flow main; hence, a 1½-inch pipe is sufficiently large to supply the radiator at *e*. It will be noted that this radiator is also provided with an independent return connection, as shown at *f*. This construction insures a good

circulation, more positive and rapid than if the return were connected into the return main at *d*. The difference is owing to the length of the horizontal branches. If the radiator were located close to the mains, there would be no considerable advantage in providing it with an independent return.

The circulation in circuit *No. 2* would probably be improved by providing the return pipe *g* with an independent connection to the boiler, instead of connecting it into the return main, as shown in the illustration.

The radiator *h*, on circuit *No. 2*, has long connections. As has been stated in Art. **55**, a given size of pipe will supply 1.72 times as much heating surface on the third floor as on the first; therefore, this radiator corresponds to one on the first floor having $48 \div 1.72 = 28$ square feet of surface. Table VI shows that a radiator of that size on a 100-foot circuit requires 1-inch pipes, and reference to Table XI shows that a second-floor radiator of 48 square feet can readily be supplied through 1-inch radiator connections, if the pipes are covered with pipe covering. If, however, they are bare, the pipe surface should be added to the radiator surface. It is therefore advisable to use a 1¼-inch pipe here, as shown.

73. Proportioning Closed-Circuit Systems.—In single-circuit systems, like Fig. 9, the size of the risers may be computed by Table X, and the size of the horizontal pipes by Table VI.

In a compound system like Fig. 13, the conditions are very different from those prevailing in an ordinary open-circuit system like Fig. 11. The water in the main circuit *r f k g*, Fig. 13, moves constantly, whether the radiators are in operation or not. The quantity passing up *r* must always be sufficient to supply all the radiators in the system, and whether the water returns to the main *g* through the several drop pipes *o*, *p*, *s* or through the main drop *k* depends on whether or not the radiators are in use.

The motive force in the main circuit depends on the height of the system, which, in this case, is four stories.

Therefore, the size of the riser should be calculated to pass the total quantity required, under the head of four stories. The case is the same as if all the radiators were located on the fourth, or top, floor.

The size of the horizontal mains *f* and *g*, Fig. 13, may be found from Table VI. In order to use the table, the total actual area of radiator surface must be reduced to its equivalent at the first floor. This is done by dividing it by the figure given for the fourth floor, in Art. 55. These pipes may be larger than the riser, but should never be smaller.

The drop pipe *o* should be increased in size as it descends. Attached to the drop pipe *s* are three radiators that use the same water successively; consequently, the total fall in temperature will probably exceed 20°. But, the average temperature in the pipe, when all three radiators are in use, should be about 20° below that in the main *f*. Therefore, it should be considered as an ordinary return pipe descending from the fourth story.

In Fig. 13, the pipe *k* may be dispensed with, if *s* is made large enough and has no valves throughout its length. If ordinary fittings are used to connect *b*, *c*, and *d* to *s*, the circulation through each of these radiators will be sluggish, because the main current will by-pass them, and any circulation through them will depend on the drop given to their respective return branches.

GREENHOUSE HEATING

GENERAL DESCRIPTION

74. Greenhouses may be heated satisfactorily with either steam or hot water, but the latter is generally preferred, because of the simplicity of the apparatus, and its adaptability for storing up large quantities of heat, the apparatus generally being made so as to contain a very large amount of water in proportion to the cooling surfaces of the greenhouse. If the fires burn low or go out, the stored heat given

out gradually serves to keep the temperature from falling too rapidly, thus protecting the plants from damage until attention is given to the fires.

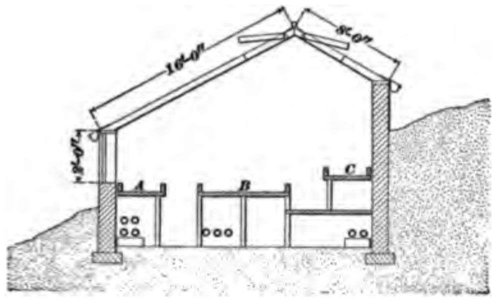


FIG. 27

Because of the fact that a hot-water greenhouse heating system requires nearly twice as much radiating surface as a

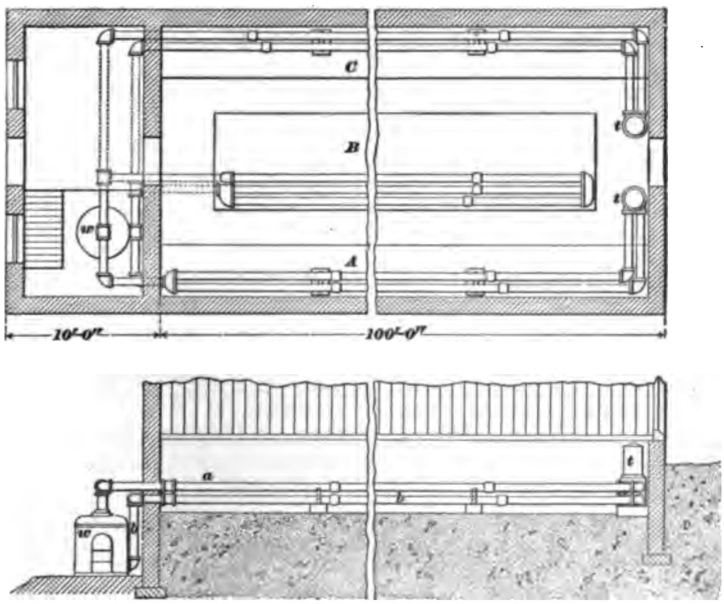


FIG. 28

steam system, the first cost of the former is from one-third to one-half greater than for the latter. Generally speaking,

however, the hot-water system is more economical in operation, and requires less attention than a steam-heating system.

75. In order to understand the requirements of greenhouse heating, it is necessary to know something of the construction and general arrangement of greenhouses. Figs. 27 and 28 show a greenhouse supposed to be located on the side of a hill. It is constructed with two or three large parallel benches, or platforms *A*, *B*, *C* that run the whole length of the building, for the purpose of holding plants that grow in pots; or they may contain beds of earth or sand in which seeds and cuttings are propagated. The outside, or wall benches, are arranged as shown in Fig. 29. A space about 2 or 3 inches wide is made at *g*, between the bench and the wall, so that the warm air rising from the heating pipes will pass upwards in a sheet, as it were, in front of the windows, and thus neutralize the downward current of cold air that would otherwise exist at that point. The front edge of the bench is extended downwards as at *f*, to insure the movement of the air up the passageway *g*, as described. The propagating benches are enclosed on both sides, part way or entirely, down to the floor, so as to retain a body of hot air in contact with the under side of the bench, or **bottom heat**, as it is commonly called. For some classes of work little or no bottom heat is desired, and only **top heat** is used, that is, the heat derived from the warm air in the upper part of the greenhouse. The apparatus must therefore be arranged, so that the heat may be applied beneath

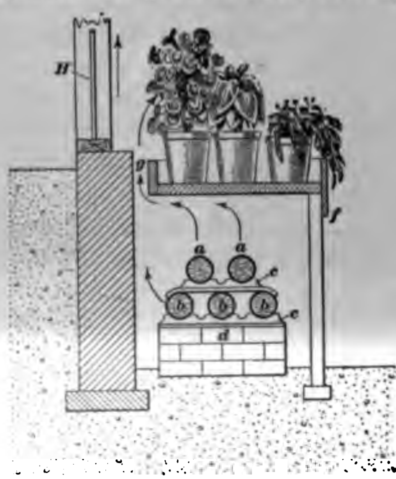


FIG. 29

the benches, or to the air in the body of the house, and sometimes to both, according to the use made of the building.

It is necessary to control the temperature at each branch, in order to grow plants to the best advantage; therefore, each set of pipes must be provided with suitable valves.

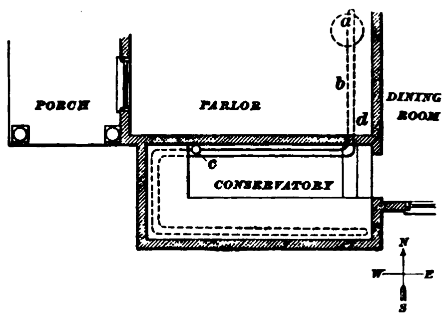


FIG. 30

When steam is used, it is necessary to place shut-off valves on every line of pipe that extends beneath the benches, and the only practicable mode of regulation is to shut off the steam from certain of the pipes. The vacuum system of steam heating is peculiarly well adapted to greenhouse service, but is usually too expensive for small greenhouses.

76. The cheapest and perhaps the most desirable form of small conservatory or greenhouse is a simple lean-to glass building, connected to the house—something like

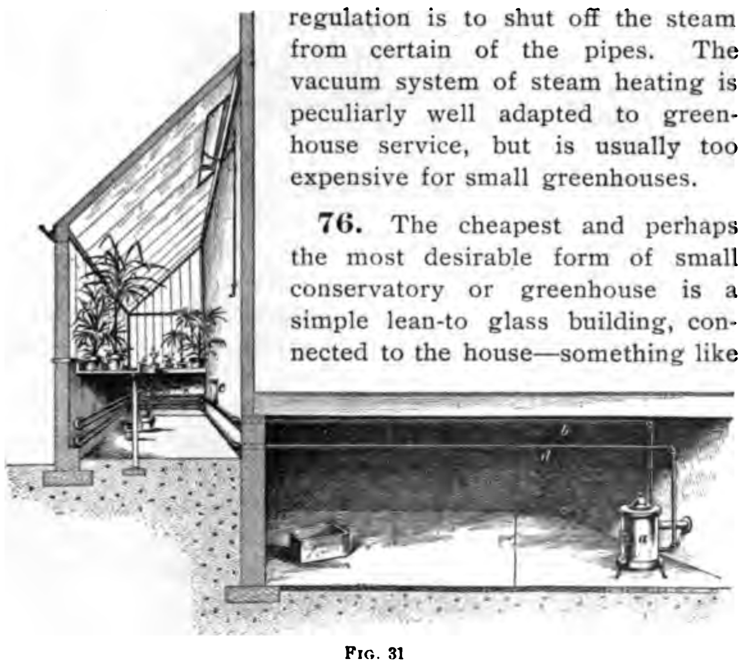


FIG. 31

that of which a floor plan is shown in Fig. 30, and an elevation in Fig. 31. If the dwelling is heated with stoves or a

furnace in the ordinary manner, the best, simplest, safest, and most economical heating system that can be used is a low-pressure hot-water system arranged as shown in Fig. 31. A small cast-iron boiler *a* is set in the cellar near the chimney. A flow main *b*, of 1½-inch black-iron pipe, is run from the top tapping of the boiler to the expansion tank *c*. A coil of four 1½-inch pipes runs from the tank and under the flower-pot benches. The lower end of the coil is continued full bore around the back of the greenhouse, and goes through the foundation wall into the cellar, and then connects to the bottom tapping of the heater, thus forming the return pipe *d* for the system. The flow pipe and all the other pipes must grade upwards toward the tank, with a pitch of not less than 1 inch in 10 feet, and all pipes must be so supported that they will not sag, because if they are not properly graded, or if they sag, air bubbles will gather in the pipes and stop the circulation of the water. With the arrangement shown, all air bubbles will escape at the tank.

The reason why the tank is placed on the flow-pipe line, instead of on the return line, is to prevent the water from being blown out of the system if the heater should generate steam; also, to allow a free escape of vapor, if necessary, by removing the loose cover of the tank. This vapor will condense on the glass and freeze, thus forming a skin of ice, which not only closes the laps in the glass, but also helps the glass to prevent loss of heat by radiation and conduction.

ARRANGEMENT OF PIPES

77. Cast-iron pipes of large diameter are commonly used in greenhouse heating, but wrought-iron pipe of the same size may also be used to equally good advantage. The pipes are usually laid in long parallel lines under the benches, as shown in Figs. 27 and 28, with one or two flow pipes *a*, Fig. 29, resting on top of two or three return pipes *b*. They are supported at intervals by brick piers *d*, at a sufficient height above the floor to secure a good supply of air to the inside of the group of pipes. They are all laid with an upward grade from the boiler to the farther end of the line.

The head available in greenhouse apparatus is seldom more than 6 feet, and is usually much less. As the buildings are frequently from 300 to 400 feet long, it is evident that the grading of the pipes must be carefully done. In order to secure as much head as possible, the boiler should be set in a pit or cellar.

The hot-water system can also be applied by using small wrought-iron pipes as for ordinary house heating. In that case, the flow main *a*, Fig. 32, should be carried overhead, near the roof, to the farther end of the greenhouse, and only the return pipes *b*, *b* should be placed under the benches. The main should be taken directly up to the expansion tank and then be graded from the tank to the farther end of the

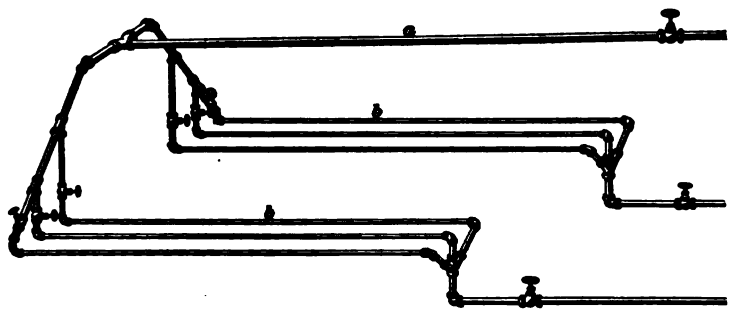


FIG. 32

greenhouse. The returns should be inclined downwards toward the boiler. For steam heating, the pipes should be arranged in the same way, so that the water of condensation will travel in the same direction as the steam, and each pipe line should be separately valved.

The pipes employed under the benches are usually $1\frac{1}{4}$ inches in diameter for steam, but for hot water the size must be governed by the length of the circuit and the head available; in any case a diameter of $1\frac{1}{2}$ inches should be the smallest size.

78. The expansion tank for a cast-iron pipe system is usually placed at the end of the line of pipe most remote from the boiler. Each line or group of pipes may be provided with an expansion tank, or one large tank may be used for the whole system. The expansion tank is usually

arranged as shown in Fig. 33. Both the flow and return pipes are connected to it as shown; it thus serves as a return connection and as a vent for air. The top is closed by a loosely fitting cover.

When the water is cold it should stand 3 or 4 inches above the opening into the flow pipe a, and the space above that level should be equal to at least one-twentieth of the volume of water contained in the whole apparatus. Of course, if several tanks are used, this space for expansion may be divided between them.

FIG. 33

In the plan view, Fig. 28, the pipes shown under the side tables are provided with separate tanks t, t, while the middle line has none, as it may be inconvenient to place a tank at the end of the middle table. These pipes are relieved of air by means of a $\frac{1}{4}$-inch or $\frac{1}{2}$-inch pipe, tapped into the highest point, and extended upwards above the level of the top of the expansion tanks. The boiler w is set in a pit, as shown in the side elevation.

79. The cast-iron pipes usually employed for greenhouse heating are connected by the ordinary spigot joints, but are not calked with lead because this is not durable in hot-water work, as the expansion and contraction of the pipes soon work the lead rings out of the joints. **Rust joints** are used instead. The cement is commonly made by mixing one hundred parts, by weight, of iron filings or borings, pounded fine, with from one to two parts of sal ammoniac, enough water being added to make the mixture into a thick mortar.

The bottom of the socket is closed by calking in a strand of oakum in the usual manner, and then the remaining space is filled with the cement and lightly calked. The sal ammoniac attacks the iron and rapidly converts it into rust, which hardens into a dense, tough mass, and clings to the iron pipe with great tenacity. Many heating engineers do not use sal ammoniac in the mixture, but calk the joints solidly and give them a longer time to harden before filling the system with water.

HEATING SURFACE REQUIRED FOR GREENHOUSES

80. The loss of heat from a greenhouse occurs principally by conduction through the glass, and to a great extent by leakage around the edges of the sashes and at the laps of the glass. The loss through the side and end walls averages one-fourth of that through an equal area of glass. When the difference between the interior temperature and that of the outside air is 70°, each square foot of glass will transmit 55 to 60 British thermal units per hour.

The pipes commonly used for hot-water service in greenhouses are slightly less than 4 inches in diameter, 1 lineal foot of pipe being equal to 1 square foot of heating surface. If the average temperature of the pipe is 100° above that of the air in the room, each square foot of pipe surface, or 1 lineal foot of the pipe, size mentioned, will emit about 165 to 180 British thermal units per hour, when the system is operating under ordinary conditions. Thus it appears that for hot-water apparatus, the area of heating surface should be about one-third of the estimated area of glass and equivalent surfaces.

With steam at 5 pounds gauge pressure, the pipes will emit about 300 British thermal units per hour per square

TABLE XII

DIVISORS FOR FINDING RADIATION FOR GREENHOUSES

Temperature in Greenhouse Degrees Fahrenheit	To Find Radiation, in Square Feet, Divide Sum of Glass and Equivalent Glass Surface by	
	For Steam	For Hot Water
45	8.0	5.00
50	7.0	4.50
55	6.5	4.00
60	6.0	3.50
65	5.5	3.25
70	5.0	3.00

foot; consequently, the heating surface may be about $\frac{60}{300} = \frac{1}{5}$ of the estimated glass and equivalent glass surface.

Table XII may be used in designing heating systems for greenhouses when the temperature difference is other than 70° F., the outdoor temperature being 0° F.

EXAMPLE.—A greenhouse having a glass surface and equivalent glass surface of 3,124 square feet is to be heated by steam and kept at a temperature 50° F.; how much radiation is required?

SOLUTION.—By Table XII, a divisor of 7 is to be used. Then, the radiating surface required is $\frac{3,124}{7} = 446$ sq. ft., nearly. Ans.

HOT-WATER HEATING APPARATUS

SPECIAL APPLIANCES

PIPE FITTINGS AND VALVES

PIPE FITTINGS

1. The fittings commonly employed in steam piping are
›t suitable for use in connection with hot-water heating
›paratus, because of the great resistance they offer to the
›w of the water, due
the angles being too
›rupt. The enlarge-
ents commonly made
pipe fittings are of
ttle consequence
hen steam flows
rough them; but they
tard the flow of water
o much in a hot-water
ating system, as the
otive force of the cur-
nt is small in pro-
›rtion to the amount
resistance offered.

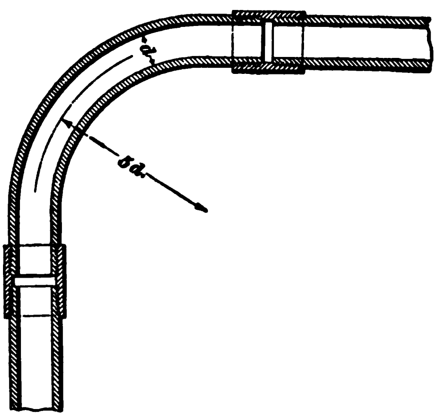


FIG. 1

bows for hot-water service should be made with a radius
ual to five times the internal diameter of the pipe, as
own in Fig. 1. Such elbows are commonly made of

wrought-iron or steel pipe, bent up to shape, and, consequently, are called **bends.**

When common pipe fittings must be employed, the retardation of flow due to extreme resistance may be somewhat lessened by carefully reaming out the ends of the pipe, as shown in Fig. 2.

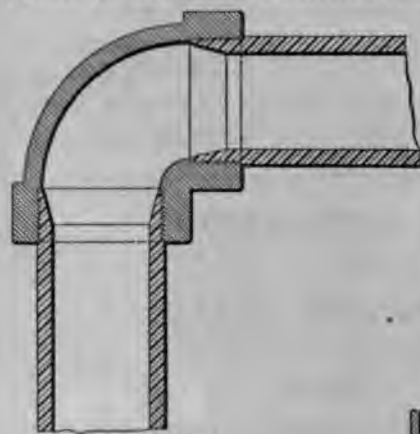


FIG. 2

The common screw union should never be used in hot-water piping; instead, the right-and-left coupling should always be employed. In large pipes flanged unions may be used.

2. The fittings for cast-iron pipe, such as those used in greenhouse heating, should always be of the variety called **flush fittings**; that is, they should have the same internal diameter as the pipes attached to them, as shown in Fig. 3. Fittings having internal beads, or shoulders, and an enlarged bore, should be discarded, as they offer too much resistance.

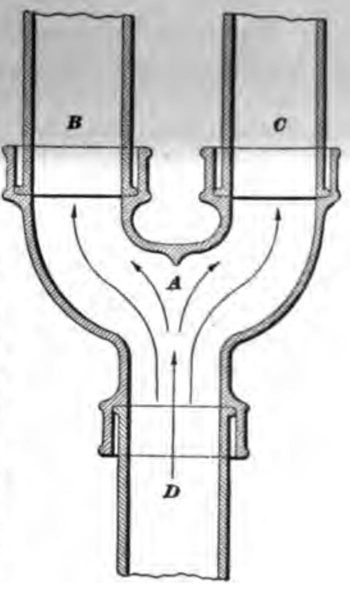


FIG. 3

3. Fig. 4 shows a group of special fittings, some of which are well adapted for hot-water heating, while others are not. The fitting *A* has large round corners between the branches *a*, *b*, *c*, making it superior to the common T, but it is not desirable for hot-water heating.

It was designed for use in cold-water piping, where the water is required to flow either way, according to the demand. In hot-water heating, the direction of the current is always the same, and the purpose can be accomplished with less resistance by using the **twin elbow** *B*. This may be used to divide a main current entering at *c* into two branches, or to combine two currents, entering at *a* and *b*, into one main.

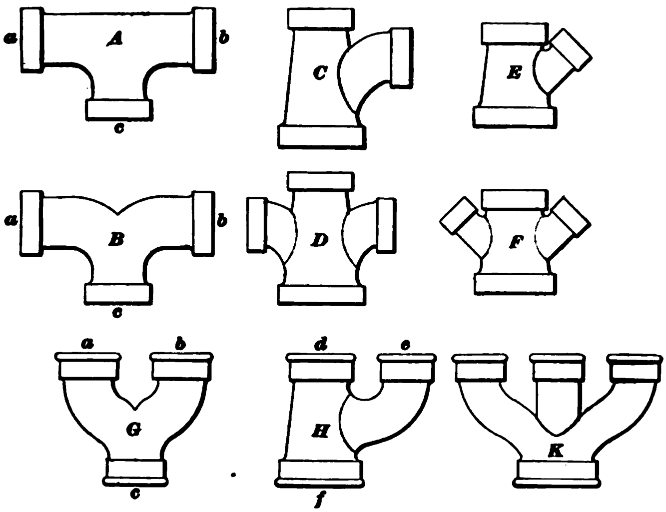


FIG. 4

If the fitting *A* is used for the latter purpose, the currents entering at *a* and *b* will oppose each other and cause great resistance at *c*.

When a branch is to be taken off a main line or is to be united thereto at right angles, the fitting *C* should be used instead of a common **T**, the curves of the branch being turned in the direction of the flow. The fitting *E* also serves the same purpose when the angle of the branch is 45° instead of 90°.

The double-branched fittings *D* and *F* are frequently used for hot-water service, but as the motive force of the water is small, there is a liability that a slight difference in the resistance of the branch circuits may cause one branch to rob the other to a serious degree. Similarly, when two return

currents are connected into the same fitting on a main, a small excess of pressure or flow in a circuit will often cause the flow in one branch nearly to block the opposite one. A safer way is to connect each branch separately to the main.

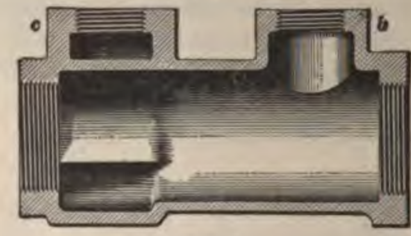


FIG. 5

The fittings *G*, *H*, and *K* are designed especially for greenhouse heating, *G* being used to divide a main current into two equal but smaller currents without changing the direction, or for uniting two currents into one, and *K* serving to divide the main current into three equal currents. The fitting *H* is used for the same purpose as *G*, but more commonly to create a greater resistance in the branch *e* than in *d*. This is sometimes necessary when the branch circuits are of unequal length or resistance.


FIG. 6

4. Fig. 5 shows a fitting designed for connecting a radiator to the supply main, in a single-pipe hot-water heating system. The flow pipe to the radiator is connected into the vertical branch *b*, and the return pipe is connected into *c*. This latter branch encircles the body of the fitting and opens into it only on the under side. The hot water in the main is supposed to pass up through *b* to the radiator, while the cooler return water flows back into the lower side of the main, the circulation through the radiator being purely local.

5. The special fitting, shown in Fig. 6, is well adapted for hot-water service. It is used in the flow pipes in place of

an ordinary **T** for lateral branches. The momentum of the rising current is utilized to drive water into the branch, and the rising pipe is prevented from taking a disproportionate share of the flow of water. It will be found especially useful in cases where the branch circuit is long and sluggish.

6. A hot-water fitting designed especially for single-main systems is shown in section in Fig. 7. It takes the hot water through *a* from the top of the main to the radiator, and receives through *b* into the bottom of the main the water that has been cooled in passing through the radiator.

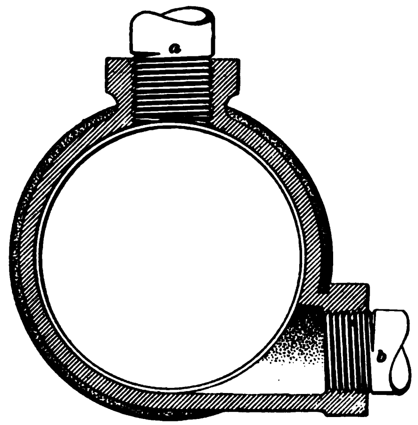


FIG. 7

The fitting is made for all sizes of pipe ranging from $2\frac{1}{2}$ inches to 5 inches, and with its radiator branches tapped for different sizes of pipe.

VALVES

7. The essential features of valves used in hot-water heating are very different from those of valves employed in steam heating or in ordinary plumbing. In the latter cases the valves must close with sufficient force to be tight against considerable pressure, but in hot-water heating the valves are required to merely check or direct a current of water having but a very small propelling force. The stems must be packed with equal care, however, to prevent leakage, and the valve bodies must be equally strong to resist static pressure and rough usage; but the valve proper, that is, the part that serves to shut the passage, may be of very light construction.

8. Globe valves offer so much resistance to the passage of water that they should not be employed in hot-water apparatus at any point. The common angle valve offers considerable resistance, but is tolerated mainly for want of something better. It may be used as a radiator valve, but it should never be used in main-line piping, because the turn is much too abrupt.

9. Gate valves should be used exclusively in all the piping of a hot-water system. The heavy internal construction employed in steam valves may be dispensed with. A light single gate is sufficient, and the powerful operating screw required for steam or water may even be replaced by a light sliding stem and lever, as shown in Fig. 8. Lever valves have advantages over valves operated by a wheel and screw, in that the position of the lever always indicates whether the valve is closed or open, and there is never any uncertainty about the proper mode of operating the valve.

Fig. 8

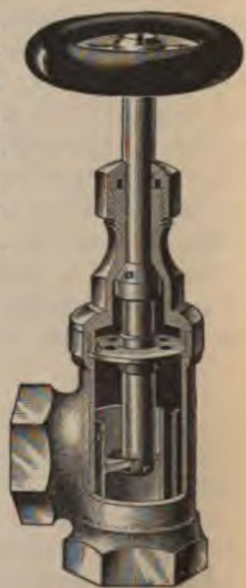


Fig. 9

10. A special radiator valve is shown in Fig. 9. The valve *d* is a light semicylindrical shell that covers the outlet port. It opens by turning the spindle part way around. The attachment to the spindle is made midway in the length of the valve, so that it opens without any tendency to twist. The spring washer *b* acts as a guide for the valve and serves

to force the conical valve *a* against its seat in the cap, and thus prevents leakage around the stem.

11. To prevent the water in a radiator from freezing when the radiator is not in use, a common practice is to have a small hole (about $\frac{1}{8}$ inch in diameter) through the valve so that a slight circulation will always be maintained in the radiator when the valve is shut. This by-pass to the valve is intended to furnish enough circulation to prevent the temperature of the radiator from reaching 32° F. when the air is near zero.

The size of the by-pass must be proportional to the size of the radiator, but in very few cases does it require to be more than $\frac{1}{4}$ inch in diameter.

Many radiator valves, on the general plan of a plug cock, have been designed for hot-water service, but they are usually so bulky that they are not desirable.

12. The **butterfly valve** shown in Fig. 10 is sometimes used in large pipes for the purpose of regulating the flow at certain points, and thus increasing the circulation through such branch circuits as would otherwise have too sluggish a movement of water.

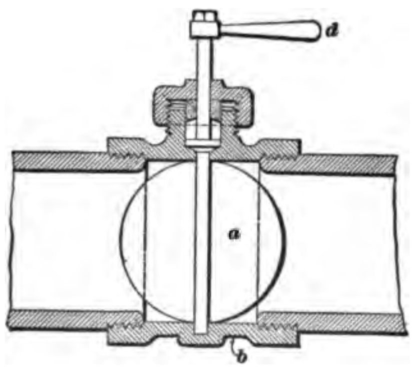


FIG. 10

The valve consists of a metal disk *a* of the same diameter as the body or shell *b*, and having a lever handle *d* by which it may be turned crosswise of the pipe to any degree desired. The diameter of the disk is obviously limited by the size of the opening at the end of the shell; and the obstruction caused by the disk when standing edgewise to the current is usually compensated for by the increased diameter of the pass way.

13. Any kind of small valve or petcock will serve as an air vent for hand regulation; but there are many situations

where the venting must be performed automatically. In **automatic vents,** the escape valve must be controlled by a float, so that it will remain closed as long as water is present, and will open only when the water is displaced by air. Air vents for steam heating are frequently constructed with a float that serves to close the vent and prevent the escape of water, but the float in a hot-water air vent operates in a very different manner. The buoyancy of the float, when surrounded by water, is depended on primarily to close the valve; therefore, it should be constructed in such a way that it can never fail to be buoyant. This can be done only by closing the float at both ends, making it perfectly air-tight.

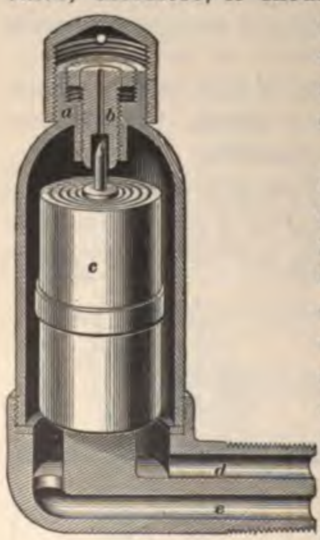


FIG. 11

The air trapped in any part of a hot-water system has the same pressure as the water, and it tends to hold the valve against its seat in the same manner as any check-valve is held shut. Therefore, the weight of the valve and float, when surrounded by air only, must be sufficient to pull the valve open against the internal pressure.

14. An air vent of good design is shown in Fig. 11. The float *c* is air-tight, and the valve seat is made in the screw *b*, which is adjustable in the neck *a*. There are two inlet openings *d*, *e* so that the movements of the air and water in entering or leaving the float chamber cannot interfere at any time.

The changes that occur in the temperature of the water in hot-water heating apparatus cannot be utilized to control the air vents.

RADIATORS AND BOILERS

RADIATORS

Radiators for hot-water heating should be con-
l of vertical tubes, connected with ample waterways
top and bottom. The continuous pipe coil that is so
e in steam heat-
; few advantages
t-water heating
quite inferior to
rtical loop radi-
own in Fig. 12.
culation in a coil
adually stop as
ects in the upper
r header, but it
ntinue in a verti-
radiator as long
level of the water
e the nipple *a*,
. If it falls be-
e nipple *a*, the
ter will diffuse
up each side of
op, while the
circulation

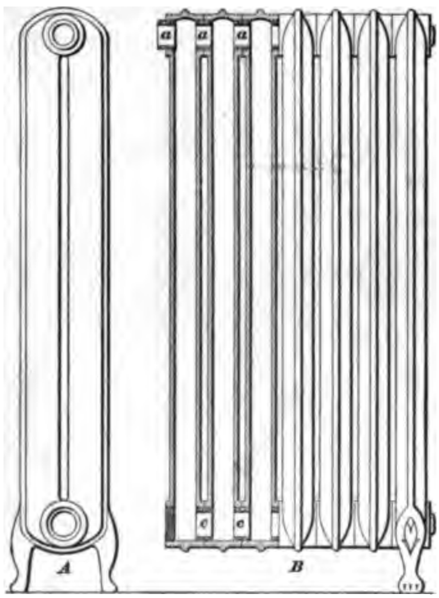


Fig. 12

directly from the inlet to the outlet of the radiator.
connections of the loops to each other at the bottom
be more than equal in area to the supply pipe, other-
e resistance will be so great as to seriously impede
in circulation.

In the **Detroit loop** radiator for hot-water heating,
, each loop is complete in itself and requires no base
ly chamber. The loops are connected together in
nber desired by means of nipples *a*, *c*. The construc-
this class of loops is often varied so that they

comprise three or even four parallel tubes. They are also modified so as to form flue radiators.

17. Fig. 13 shows a cross-section (a) and sectional side

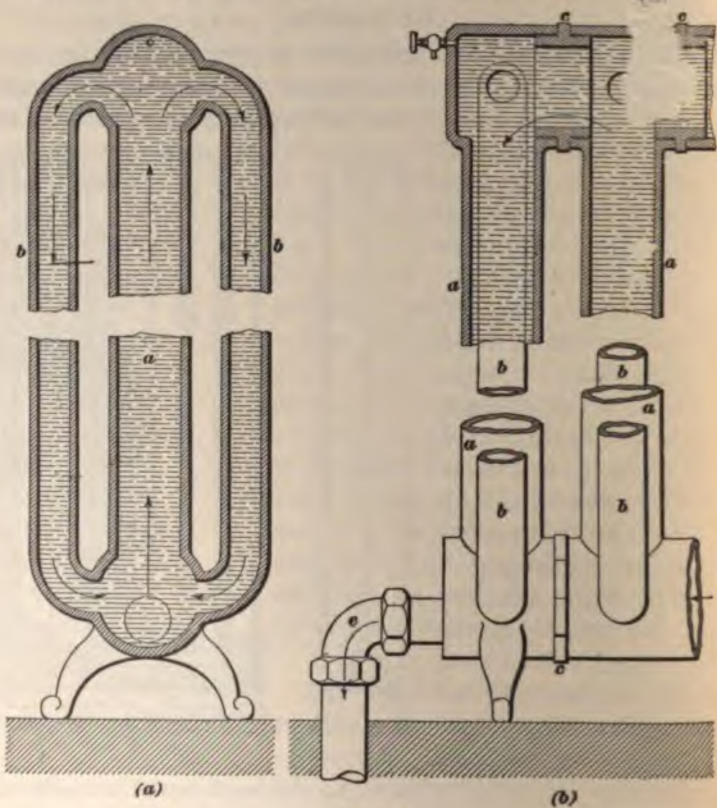


FIG. 13

view (b) of a radiator composed of three-column sections that is peculiarly adapted to the use of hot water. Both the supply and return pipes are connected at the bottom. Each loop consists of three tubes: a large middle tube a up which the hot water ascends, and two smaller side tubes b, b by which the cooled water descends to the return pipe e. The loops are connected at the top and bottom by nipples c, c large enough to provide an ample waterway.

18. Hot-water radiators must have two connections, one for the inlet and the other for the outlet. They cannot be operated successfully with a single connection. The supply may enter the top or bottom of the radiator, but the outlet should connect to the bottom.

In using hot-water radiators for indirect heating, particular care must be taken to prevent them from being frozen by circulation being shut off. The best preventive is simply to connect such radiators direct to the system without any controlling valves being attached to them. This will insure a constant circulation while there is fire in the boiler.

19. To obviate the cutting of carpets and to overcome the effect of unevenness of floors, radiators are sometimes set on adjustable stands, or **leg rests**, such as that illustrated in Fig. 14. The upper part *a* contains a threaded stem *b* that screws into a threaded socket in *c*. Thus, *a* can be raised or lowered to suit the height of the radiator foot above the floor.

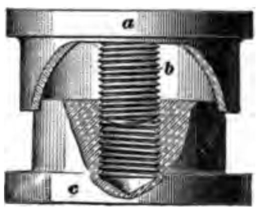


FIG. 14

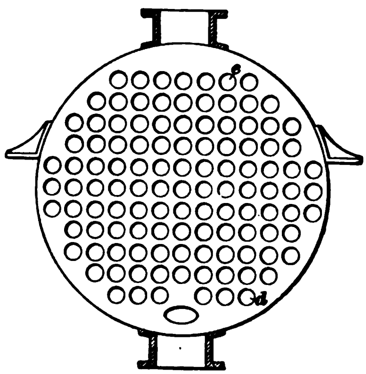


FIG. 15

BOILERS

20. The **boilers** used with hot-water heating systems are in all respects similar to the best forms of steam boilers, except that the spaces commonly reserved for steam room may be dispensed with, or may be utilized for tubes and other heating surfaces. Thus, in a common tubular boiler the entire shell may be filled with tubes, as shown in Fig. 15.

The circulation in many parts of a hot-water boiler is apt to be much slower than in a steam boiler. The cold water enters at the bottom, and when heated passes out at the top; the general movement is, therefore, upwards, and there is only a moderate local circulation within the boiler. The local convection currents move comparatively slow, because the difference in weight of the ascending and descending parts is small, the actual working height of such local circuits seldom exceeding 2 or 3 feet. The water should pass from the inlet, over the heating surfaces, to the outlet in the most direct manner and with the least possible resistance.

21. The aids to circulation that are so commonly and successfully used in steam boilers are of little or no value in a hot-water boiler. Thus, circulating tubes can rarely be used to any advantage; and drop tubes, which add so largely to the capacity of a steam boiler, have no advantages for heating water, because there is no practicable method for maintaining a rapid circulation through them.

In a steam boiler the depth of water is comparatively small, and the circulation is greatly increased by the formation of multitudes of steam bubbles that mix with the ascending water and make it much lighter than an equal volume of the descending parts of the current. The heating surfaces in a hot-water boiler are, however, usually 40 to 60 feet, or more, below the surface of the water in the expansion tank, and the formation of steam bubbles on the heating surfaces is not desirable, because it is likely to be accompanied by loud rumblings and snapping noises. The bubbles of steam condense on coming in contact with the colder parts of the water and water hammer is the result.

22. The area of heating surface required in a hot-water boiler for a given transmission of heat is the same as in a steam boiler working at the same temperatures of water and combustion. The required areas of grates and chimney are also about the same.

The numerous varieties of hot-water boilers now on the market differ greatly in the volume of water that they

contain, although they have equal heating power. A heating system that contains only a small amount of water can be heated quickly, but it will also cool quickly; while, if the volume of water is large, it will act as a reservoir of heat and will maintain a moderate temperature for a considerable time after the fire has failed.

23. The common return tubular boiler shown in Fig. 16 is quite frequently used for hot-water service. The number of tubes, however, is usually increased, as shown in Fig. 15. The brickwork is arched over the top of the shell, and the hot gases of combustion are permitted to pass all around the

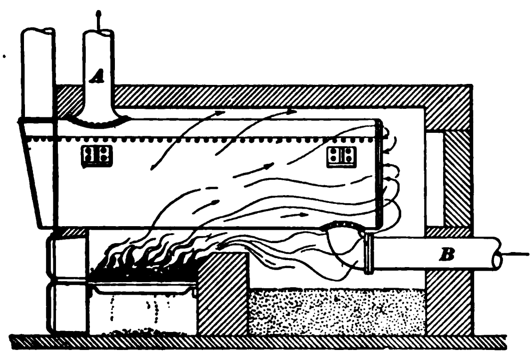


FIG. 16

boiler before they enter the tubes at the rear end. The riser *A* and the return pipe *B* are made conical where they join the shell, to facilitate the flow of the water as much as possible. Care must be taken in locating the upper and lower rows of tubes *e*, *d*, Fig. 15, to avoid obstructing the inlet and outlet connections.

24. A **cast-iron sectional hot-water boiler,** commonly used for heating dwellings is shown in Figs. 17 and 18, the latter figure showing the interior construction and the arrangements of the parts. The several sections are united by packed joints at *a*, *b*, Fig. 18, and are clamped together by bolts at *d* and *e*. The furnace is inside the boiler, and even the ash-pit is surrounded with water. The hot gases

pass to the rear section and then to the front end through the flues *g*, and return to the smokestack *k*, Fig. 17, through the upper flues *h*, Fig. 18. The boiler rests on a base block *c*, Fig. 18, that maintains it in a proper position. The main pipes are connected by risers *f*, Fig. 17, to the top of the boiler, as shown.

FIG. 17

25. Fig. 19 shows a **greenhouse boiler.** The characteristic feature of this class of boilers is that they are made as low as possible, in order to adapt them to the very small hydraulic heads commonly found in greenhouse work. In some cases the head does

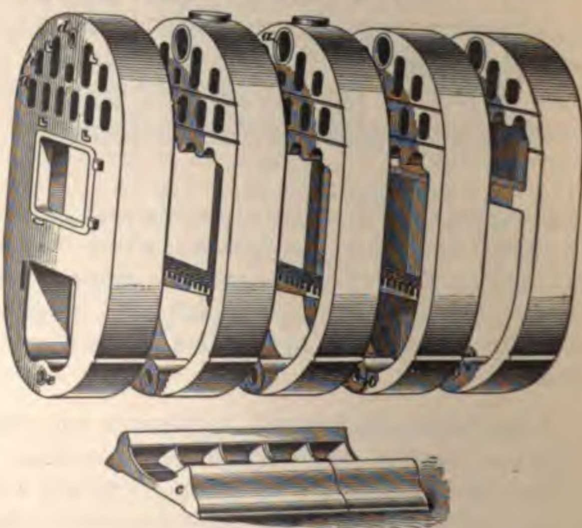


FIG. 18

not exceed 1 foot, and the boiler must, therefore, be designed to offer the least possible resistance to circulation.

The sides and top of the firebox are corrugated to secure the maximum of heating surface. The water enters the leg of the boiler at *a* and passes out at *b*. The hot

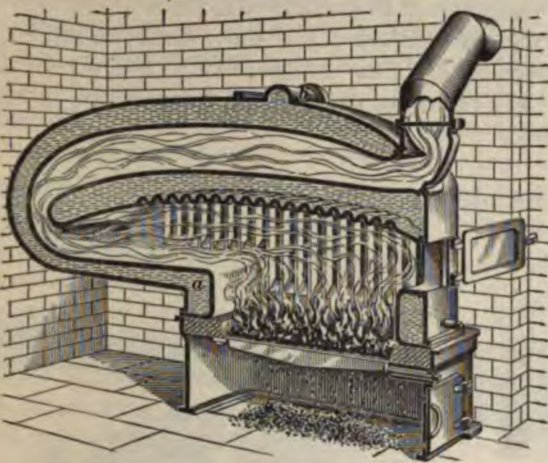


FIG. 19

gases of combustion are spread out over large heating surfaces and have ample time to impart their heat to the water before escaping to the chimney.

BOILER TRIMMINGS

DRAFT REGULATORS

26. Introduction.—It is more difficult to regulate the draft automatically in a hot-water heater than in a steam boiler. In the latter case the regulator is operated by the pressure of the steam, which is nearly the same in all the pipes that lead from the boiler. In a hot-water apparatus, however, only the temperature varies to any considerable degree, but it does not vary to the same extent in the several risers or mains that are connected to the heater. Thus there may be an active circulation in one riser, while there is little or none in the others, owing to the radiators being out of use, etc. If

the draft regulator is connected to any pipe that does not take the whole flow, it will be governed by the temperature prevailing in that particular part of the system, instead of by the average temperature of the entire system. The best method in such cases is to construct a short direct circuit especially for the regulator. The temperature in this circuit will correspond very nearly to the average temperature of the water in the boiler.

27. Diaphragm Damper Regulator.—Fig. 20 shows, in perspective, a section of type of damper regulator commonly employed for automatically controlling the draft of

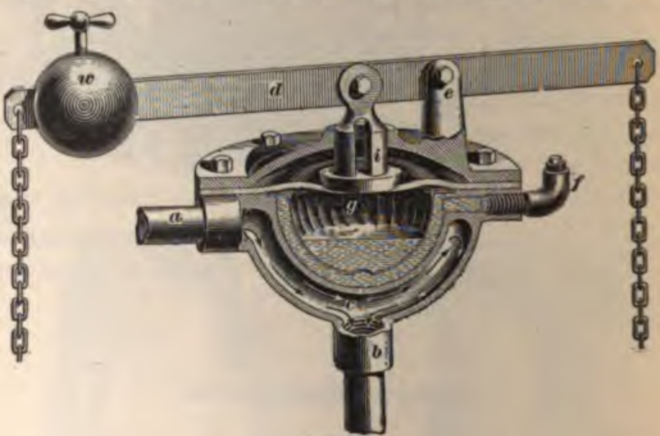


Fig. 20

hot-water boilers. It is arranged over or near the boiler, and is connected to the main circulating current in such a manner that a circulation of hot water will be maintained in the regulator. This is accomplished by joining the inlet *a* to the top of the boiler or the flow main, that is, the main pipe that conveys hot water from the boiler to the radiators and their supply branches, and also by joining the outlet connection *b*, to the base of the boiler or the main return pipe, that is, the main pipe that leads the water from the radiators to the boiler to become reheated. It will thus be seen that the cavity *c* will have a temperature nearly equal to that of the

water in the boiler. When the boiler temperature changes, the temperature of the regulator will also change. Immediately above the cavity, or water-jacket, *c* is a hemispherical chamber closed by a rubber diaphragm. Some liquid having a low temperature of vaporization, such as alcohol, which boils at a temperature of about 173° F., at the pressure of the atmosphere, is poured through *f* into the upper chamber until the orifice at the bottom of the corrugated copper cup *g* is sealed, and air is thereby confined in the cup. A plug is then screwed into *f*, making the top chamber an air-tight space.

The operation of the regulator is as follows: At first, as the water that circulates through *c* increases in temperature, heat is transmitted from it to the alcohol and air in *g*, causing them to expand and increase the pressure in the chamber *g*. Consequently, the rubber diaphragm will be bulged up in the center, provided that the upward pressure on the diaphragm is greater than the downward pressure exerted by the stem *i*. When *i* is raised, the loaded end of the lever *d* rises with it and the other end falls; consequently, since the dampers are connected, by chains, to the lever ends, they will be opened or closed, as the case may be. The motion of the lever *d* is slight at first, but as the alcohol increases in temperature, it soon begins to boil, and the pressure is thereby increased. Thus, at a temperature of 176° F., the gauge pressure in the top chamber will be 1.12 pounds per square inch; with a temperature of 194° F., a gauge pressure of 8.32 pounds per square inch will be obtained; and with a temperature of 212° F., which is below the boiling point of the water in the ordinary hot-water boiler, a gauge pressure of 17.9 pounds per square inch will be had in the alcohol chamber. This pressure is sufficient to open or close any ordinary damper. The weight *w* can be moved along the lever *d* and be secured at any point by a setscrew. The object of moving this weight is to set the apparatus to operate at any desired temperature. Thus, during moderate weather, when the building can be comfortably warmed by water having a moderate temperature, the weight will be set near the stem *i*, so that the downward pressure exerted by *i*

on the diaphragm will not exceed the upward pressure of the alcohol in the regulator when it reaches that temperature. If a higher temperature of the water is required to keep the building warm, the weight should be set near the end of the lever, as shown in the illustration. The downward force exerted by *i* will then be increased and the upward force due to the vaporization of the alcohol must also be increased before the dampers will operate. It will thus be seen that the temperature of the heating medium is regulated to suit the requirements for warming the building by simply regulating the supply of air to the burning fuel on the grate.

28. Metallic-Expansion Damper Regulator.—In Fig. 21 (*a*) is shown a side elevation and in Fig. 21 (*b*) a sectional plan view of an automatic damper regulator, the operation of which depends on the expansion and contraction of a brass or copper tube. The apparatus is so constructed that it may be connected to the heater either in a horizontal or vertical position; the illustration shows it in a vertical position. The pipe *a* connects to the top and *a'* to the bottom of the heater, so as to allow a free circulation of the hot water through the thermostatic tube *b*, which is made of brass or copper. The free end of the lever *c* is attached to a flat strip *d* by a pin, as shown. The strip is placed in the length of chain that operates the damper. The upper chain *e* may be connected to the check-damper in the smoke pipe, and the lower chain *f* may operate the draft door to the boiler. The coil spring *g* is fastened to the flat strip *d* and chain *f*, so that the spring will yield should the chain become shortened by twisting, thus preventing damage being done to the thermostat.

When the tube *b* is being heated it will expand, drawing the arms *h*, *h'* inwards, whereby the lever *c* is operated by straps *i*, *i* pushing outwards against the lever link *j* at the bottom. The arms *h'* at the same time pull the upper end of the link inwards, thus producing a movement that causes the free end of the lever to be lowered, thus closing the draft to the heater.

In connecting up the dampers with the regulator it is important that there be no lost motion, so that the slightest difference in the length of the tube *b* will be transmitted to lever *c*. When it is desired to place the thermostat in a

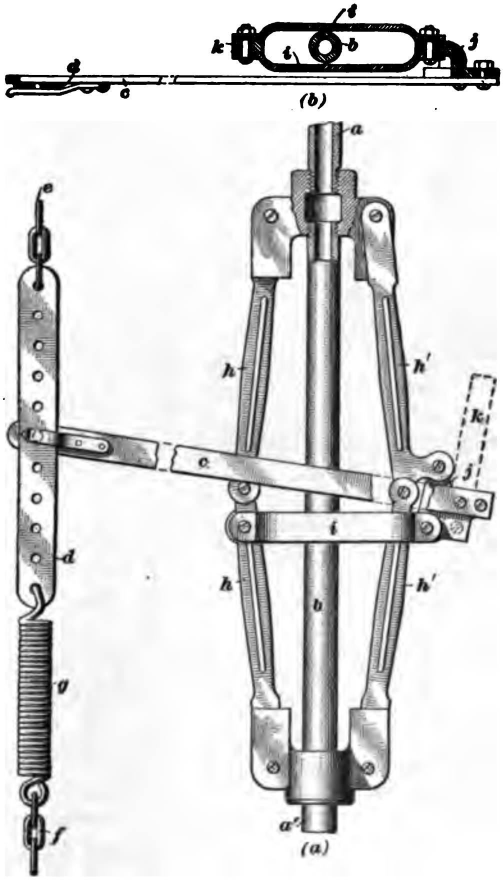


Fig. 21

horizontal position, the lever *c* is connected to the link *j* as shown by the dotted lines at *k*, the operation being the same either way.

29. Fig. 22 shows how the operation of a hot-water boiler or heater *a* can be governed automatically

either by changes in temperature of the water in the heater or by changes in temperature of the air in the room above.

The regulator *b* is attached to the flow pipe that supplies hot water to the room where the temperature is to be regulated. It is connected by a small tube *c* to a thermostat *d* in such a manner that it can also be operated by changes of temperature of the air in the room. The draft of the furnace is regulated by two dampers *e*, *i* connected, by chains, to the lever arm *d* of the regulator. It will be seen by the illustration that when the regulator lever is raised, the check-damper *e*, which is simply a hinged door fitted over an opening into the side of the smoke pipe *n*, will be closed, and the ash-pit damper *i* will be opened; fresh air will thus have easy access through the fire, and will, of course, increase the rapidity of the combustion of the fuel. If the regulator arm is lowered, and the motion of the chains thereby reversed, *e* will open and *i* will close; this will cut off the supply of air to the fuel and the boiler will cool down.

Fig. 22

The object of opening *e* when *i* is closed is to allow the atmosphere to freely flow into the chimney, and thus prevent the formation of a partial vacuum in the furnace, which might be the means of drawing enough air through joints and crevices in the ash-pit castings to allow the fuel to

burn more rapidly than is desired. The damper *e* would not be required if the ash-pit were perfectly air-tight when *i* is closed.

ALTITUDE GAUGE

30. The **altitude gauge,** shown in Fig. 23, is a very useful appliance that is usually placed at the heater in the cellar or, if desired, in any other part of the house, to indicate at all times the exact level of the water in the expansion tank, making it unnecessary for one to go to the top of the house to look at the gauge glass on the tank. The scale of the gauge is graduated in feet, and the position of a large pointer *a* gives the exact indication of the height of the water in the system. After the gauge is attached the expansion tank is filled to the desired level; the small telltale hand *b*, which is frequently made red in color, is then set to correspond to the indication of the large pointer. When the larger pointer falls below the red telltale hand *b*, it shows just how much the water has fallen below the desired level in the expansion tank and thus indicates whether refilling is necessary.

FIG. 23

The gauge is usually made with a black dial and with white figures and graduations to facilitate the reading.

THERMOMETER

31. The construction of **thermometers** for use on hot-water heating boilers is illustrated in Fig. 24. At (*a*) is shown part of the thermometer, with the scale *a* and thermometer

tube *b* broken off; the bulb of the tube is surrounded by wire netting. At (*b*) is shown the detached thermometer cup containing mercury. The stem *c* fits in the recess *d*, and is held in position by a setscrew at *e*. The mercury bath, into which the bulb of the mercury tube is immersed, is designated by the letter *f*. The mercury is a conducting medium for

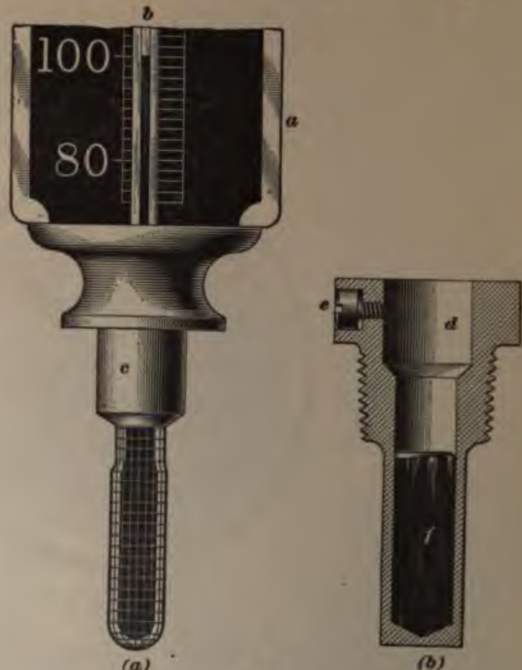


FIG. 24

the heat of the hot water, and insures a quick conduction of heat from the water to the thermometer bulb. The mercury cup, which is made of steel, the outside being heavily copper plated to prevent corrosion, is provided with $\frac{1}{2}$-inch iron-pipe thread.

32. To indicate accurately and instantaneously, the thermometer must have the entire metallic stem below the thread fully immersed in a continuous circulation of the hot water; if placed on the top of the boiler it must not be attached =

that the bulb or stem is lifted above the circulating water; a flush bushing should be used. The thermometer should not be screwed into T's, elbows, or nipples where the circulation is defective.

Should small particles of mercury become separated from the main column, either through jarring or use; they can be easily connected again by heating the thermometer in hot water to about 180° or more, and then turning it upside down and running the mercury to the top of the tube, continuing to run the mercury back and forth until it connects again. Should the mercury not flow freely or fail to connect when turned upside down and shaken, tap the top gently on a wooden bench or table.

In screwing or placing the thermometer into a heater or pipe, it should not be tightened any more than is necessary to secure a close fit. If the thermometer does not face in the right direction when screwed up tight, loosen the small setscrew *e* slightly and turn the top of the frame as desired, after which tighten this small screw again. In turning the top, do not lift it but press down on it.

In taking the base or lower portion of the thermometer apart for examination, it is necessary to be careful not to turn it upside down and thus spill the mercury. It is essential that the socket or base should contain mercury, as otherwise the thermometer will not register correctly.

AUXILIARY APPLIANCES

EXPANSION TANKS

33. The purpose of an **expansion tank** is to keep the pipes and other apparatus constantly full of water. The water in the heating system expands when heated, and if it fills the apparatus when cold it will overflow when hot; the expansion tank serves to receive this overflow.

The construction of an ordinary low-pressure expansion tank is shown in Fig. 25. The body *a* and heads are made

of wrought iron, and should be galvanized inside and out. A glass water gauge *b* is attached to show the height of the water inside. The tank is connected to the heating apparatus by an *expansion pipe c*. The top of the tank is always open to the atmosphere through the pipe *d*, and this opening must never be closed. A connection to the cold-water house supply pipe may be made at *e*, for convenience in filling the tank. Some expansion tanks are provided with ball-cocks, by means of which water is supplied to the tank automatically.

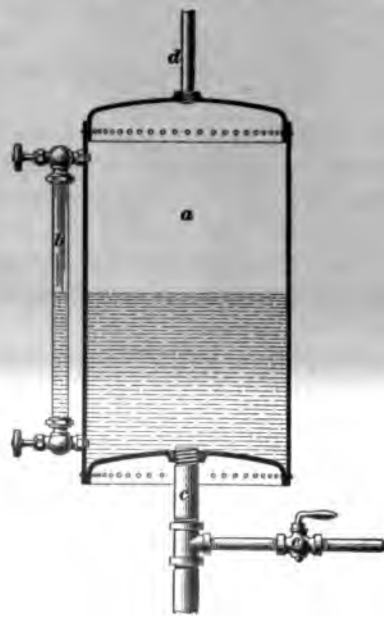


FIG. 25

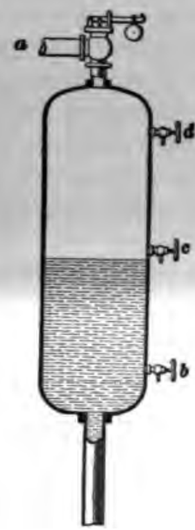


FIG. 26

34. The connection of the tank to the heating apparatus must be carefully protected against frost. When this connection is frozen, the apparatus is deprived of the relief afforded by the tank, and a rupture is sure to occur in some weak part when the water is being heated. Open communication between the expansion tank and the boiler must be maintained at all times. No stop-valve should ever be placed on this pipe, and wherever one is found it should

be removed. Such a valve is liable to be closed, and thus produce disaster.

35. An expansion tank suitable for high pressure is shown in Fig. 26. It differs from the form shown in Fig. 25 mainly in its proportions, being of smaller diameter in proportion to its length; it is also made of much thicker material. The outlet pipe is controlled by a safety valve *a*. The height of the water is shown by means of the gauge, or try, cocks *b*, *c*, *d*. Glass water gauges are not suitable for high-pressure tanks, because they are apt to crack and burst, and thus allow the water to escape and damage the building.

36. It is very essential that a closed, or high-pressure, hot-water heating system be provided with means to prevent the accumulation of a dangerous pressure that would burst the pipes, boiler, or radiators. The expansive force of the water is practically irresistible, and unless room is provided for expansion, it will burst the apparatus. The only mode of securing safety is to provide the closed tank with a safety valve. This may be set to blow off at the pressure that steam would have at the maximum temperature desired in the apparatus. No closed tank should be installed without a safety valve.

A hot-water apparatus having an open tank is absolutely safe from accident by bursting so long as open communication exists between the tank and boiler. But, if the tank is closed for any reason, or its connections are closed, it becomes dangerous.

COMPENSATING APPARATUS

37. An expansion tank is not absolutely necessary as a provision for expansion of the water and keeping the apparatus properly filled; so-called **compensating apparatus** may be employed instead. Thus, in an ordinary low-pressure system, the apparatus may be closed at the top and be connected at the bottom to the cold-water pipe of the plumbing system, in the same manner as the ordinary kitchen

boiler. Of course this should not be done unless the pressure in the street mains is high enough at all times to raise the water to the top of the building. When the apparatus is fired up, the increased bulk of water resulting from expansion will flow back into the street mains. A safety valve must always be provided, however, to prevent overpressure in case the connection to the street main is shut off or is frozen. A check-valve may be placed in the supply pipe to the boiler, so that the apparatus cannot lose any of its water by a fall of pressure in the street mains. Danger from overpressure due to expansion of the water is obviated by the safety valve, the overflow from which may be conducted to any convenient point of discharge.

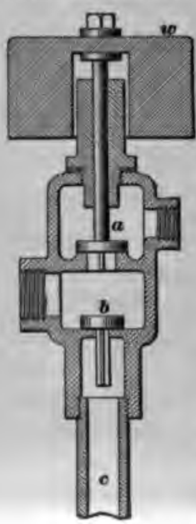


FIG. 27

High-pressure heating apparatus may be arranged in a similar manner. The expansion tank is omitted, and a double valve constructed about as shown in Fig. 27 is used instead. The ordinary dead-weight relief, or safety, valve *a* permits the excess of water resulting from expansion to escape. The ordinary check-valve *b* permits fresh water to enter and keep the pipes full when the apparatus cools off. The pipe *c* extends to any convenient source of supply.

The open-expansion-tank method of compensation is, however, the safest, simplest, and altogether the most desirable method known.

CENTRAL-STATION HEATING

STEAM HEATING PLANTS

THE CENTRAL STATION

INTRODUCTION

1. The disagreeable labor and uncleanliness necessarily associated with the operation of hot-air furnaces and steam and hot-water heating boilers has led to the widespread development of centralized heating plants, by which steam is supplied to buildings from street mains, in a manner similar to that employed for the distribution of gas and water.

To the consumer, some of the advantages in using steam delivered from a central station, instead of generating it in his own boiler, are: No fires to build and look after; increased cleanliness, due to the absence of coal, ashes, and smoke; a more uniform supply and more even distribution of heat throughout the building than with the use of stoves, a furnace, or a steam or hot-water heater; increased amount of available space due to absence of boilers, coal bins, ash piles, etc.; no depreciation of apparatus; increased safety from loss by fire; life and health not jeopardized by coal gas nor boiler explosion; a simple means always at hand for heating water for baths, laundry, and other purposes; stores, offices, and residences more rentable, being usually occupied in preference to others.

2. Simplicity and durability are among the advantages claimed for the steam system, as with the latter but one main

is required, whereas two mains are usually necessary in heating by means of the hot-water system. Further, as less radiation is required, the investment for radiators is less with the steam system than with the hot-water system. Buildings already equipped for hot-water heating may be served satisfactorily by the steam system, but those equipped for steam heating cannot be adapted for hot-water heating except at considerable expense for reconstruction.

Where buildings are already equipped for heating by hot-water radiation and the occupant desires to continue the use of the hot-water system, this may be accomplished satisfactorily and successfully by the use of a steam-heated hot-water boiler, the supply of steam to this boiler being taken from the street steam supply main, the temperature of the circulating hot water being controlled by a thermostat, and the steam used being metered in the ordinary way. With the steam system, leaks may be repaired, valves repacked, etc. without shutting off the whole or a large part of the system.

Another decided advantage of the steam system lies in the fact that the quantity of steam used by any or all customers may be readily ascertained through the use of a meter, and paid for accordingly, which is eminently the most fair and equitable method both to the consumer and to the company furnishing the steam.

3. Generally speaking, heating from a central station is feasible only in thickly settled communities, or in places where there is such a demand for steam as may be readily and economically supplied by a central station. A system of heating from a central station, which mode of heating is generally known as the **district system of steam heating**, comprises a central station in which steam is generated by several batteries of large boilers, and from which steam for heating all kinds of buildings is distributed through underground piping laid in the streets. The same general laws that govern the design and installation of isolated steam and hot-water heating plants also apply to central-station heating systems.

LOCATION AND EQUIPMENT OF STATION

4. As a rule, the most suitable location for a heating station is found somewhere on the outskirts of the business or most thickly built-up residence section of the city, or town, where fuel and water are easily obtained, and where there is ample room for future growth due to necessary extensions of the system to supply new customers.

Since the character of the station equipment depends on local conditions that frequently involve the supply of light and power as well as steam for heating, no general rules governing the selection of apparatus can be formulated. An equipment that would be perfectly satisfactory for a comparatively small central heating plant would not be at all suited to the requirements of a more extensive system for heating a large number of buildings in a town or portion of a large city. Generally speaking, the steam-generating equipment of most central heating plants consists of return-tubular boilers, but in large cities, where it is necessary to provide the greatest possible capacity within the least space, and at the same time to insure safety from disastrous explosions, boilers of the water-tube type are employed.

The arrangement of the various lines of piping, and the location and arrangement of the various accessories, such as feed-water heaters, purifiers, separators, economizers, feed-pumps, injectors, etc. necessarily differ with each installation. An elaborate plant may be fitted with economizers, mechanical stokers, coal conveyers, ash conveyers, purifiers, and other labor-saving and fuel-saving devices. On the other hand, the plant used for heating purposes often consists simply of boilers, chimney, and feed-pumps.

The actual capacity of a central heating plant is usually made about 20 per cent. in excess of its capacity as calculated on the basis of supplying 30 pounds of steam per hour per 100 square feet of direct radiating surface. Under favorable circumstances, a central plant using exhaust steam for heating will supply from 10,000 to 12,000 cubic feet of space per boiler horsepower, depending on the character of the building.

5. The extra coal required by an electric station to supply steam for heating depends on a multitude of conditions and cannot be determined in any way other than by a careful examination of the conditions surrounding each individual case. The maximum, minimum, and average electrical output; the style and make of engines in use, and, if compound engines, their cylinder ratios; the amount of the heating load; and the average back pressure carried, as compared with the regular operative conditions, are factors that must enter into the calculation. As a matter of fact, to a very large degree, the engine acts as a reducing valve between the high pressure carried in the boilers and the low pressure carried in the heating mains; it transforms, from heat energy into mechanical energy, from 10 to 15 per cent. of the heat passing through it, leaving from 85 to 90 per cent. of the heat energy for heating.

UNDERGROUND DISTRIBUTING SYSTEM

STEAM SUPPLY

6. The pressure required to circulate an adequate supply of steam, through the street mains, to the radiators within the buildings to be heated, depends on the design and extent of the distributing system. The pressure at the station may be as low as 1 pound per square inch when the radiating surface to be served is within a comparatively short distance of the plant, while a pressure of 10 to 20 pounds at the station may be required to force a supply of steam to the radiating surface at the end of mains several miles long and supplying steam to heat several million cubic feet of space. Ordinarily in the direct-, or live-steam, heating plant, the street-main, or primary, pressure is reduced at the point of use by means of a reducing valve, through which the steam flows from the street-service connection into the piping system and radiators throughout the building to be heated, the indoor, or secondary, pressure being controlled by a regulator to suit the requirements of the consumer.

When exhaust steam is utilized in heating from a central station, the most satisfactory results are obtained when the distance of transmission does not exceed $1\frac{1}{2}$ miles. With a back pressure of 4 pounds on simple non-condensing engines, an approximate heating-capacity rating of any light and power station may be obtained by allowing 150 square feet of radiation per engine horsepower. It is customary to allow from 4 to 6 square feet of radiation per pound of steam exhausted by the engines, depending on the distance of transmission, losses in mains, etc. In laying the distributing mains of an exhaust-steam heating system, it has been found an advantage to connect mains on parallel streets by lateral branches for the purpose of securing a more equable circulation.

For use in connection with central heating plants, such as are frequently installed for heating the various buildings of a university or state institution, the vacuum system of heating is well adapted. Smaller piping may be used because of the greater efficiency and rapidity of circulation due to the increased pressure drop that accompanies the use of the vacuum system. Moreover, with this system, the water of condensation may be lifted readily from varying lower levels to a higher one.

LOSSES FROM UNDERGROUND MAINS

7. The distribution of steam through an extensive system of piping involves loss of heat by conduction and radiation, and loss of pressure due to the frictional resistance offered by the piping to the flow of steam; both losses increase directly with the length of the piping. The loss in pressure increases as the square of the velocity of flow of the steam, as well as with the frictional resistance of the piping, while the loss of heat by conduction and radiation increases with the diameter and temperature of the pipes, and with the radiating and conducting powers of the pipe coverings. While an increase in diameter lowers the loss of pressure due to friction, a greater loss of heat by radiation

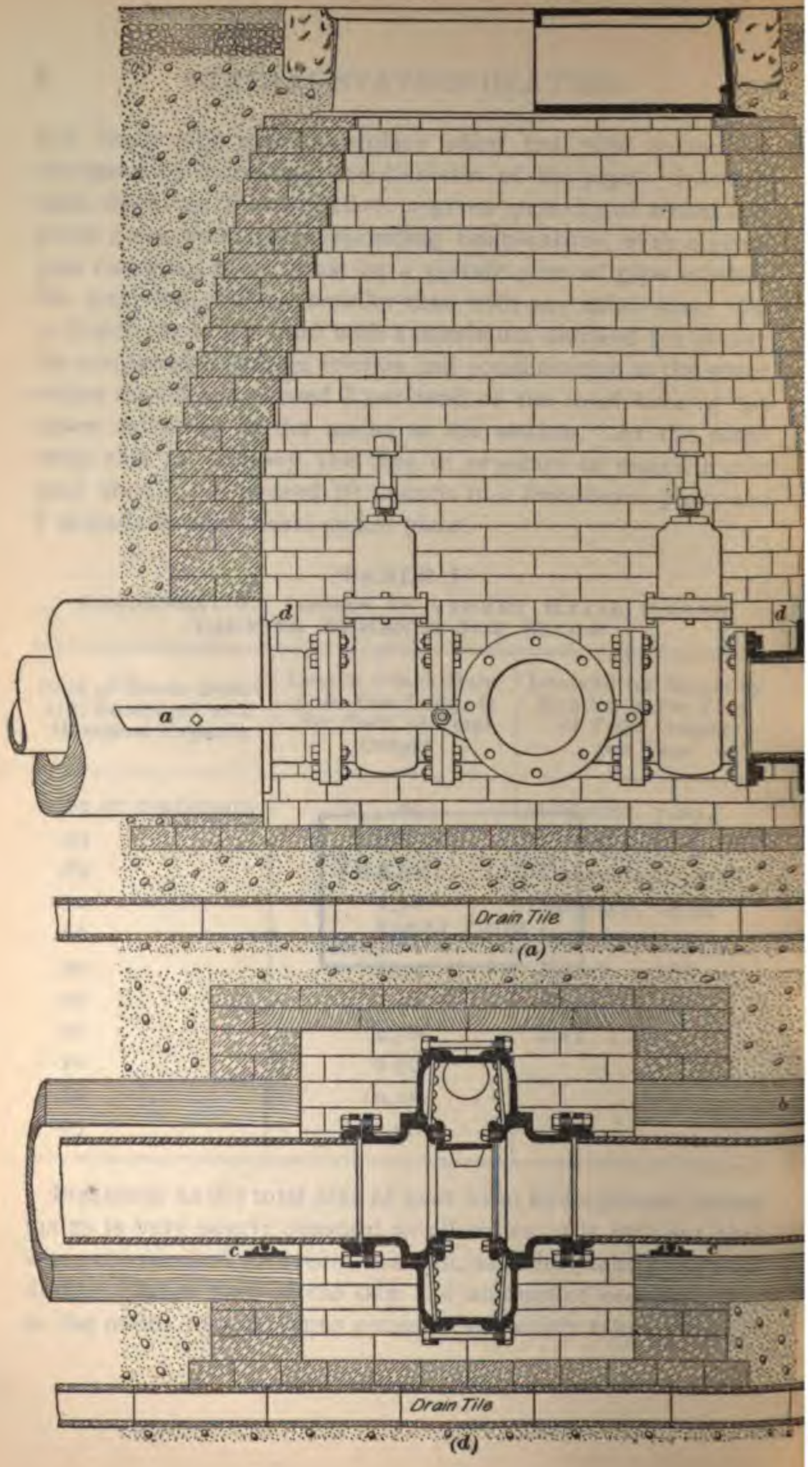
and conduction may take place when the pipe surface is increased by increasing the diameter of the pipe. It is evident, therefore, that to deliver a given quantity of steam at a given pressure and corresponding temperature, with a given pipe covering, there must be a certain size of pipe wherein the total loss will be smaller than with any other size. Up to ½ mile in length, and with a maximum demand for steam, the combined loss from friction and condensation in the street mains should not exceed 2 per cent. of the total heat of the steam delivered to the mains at the station. At the maximum rate of delivery, the loss in pressure in mains 1 mile long should not exceed 10 pounds in a live-steam plant and 3 pounds in an exhaust-steam plant.

TABLE I

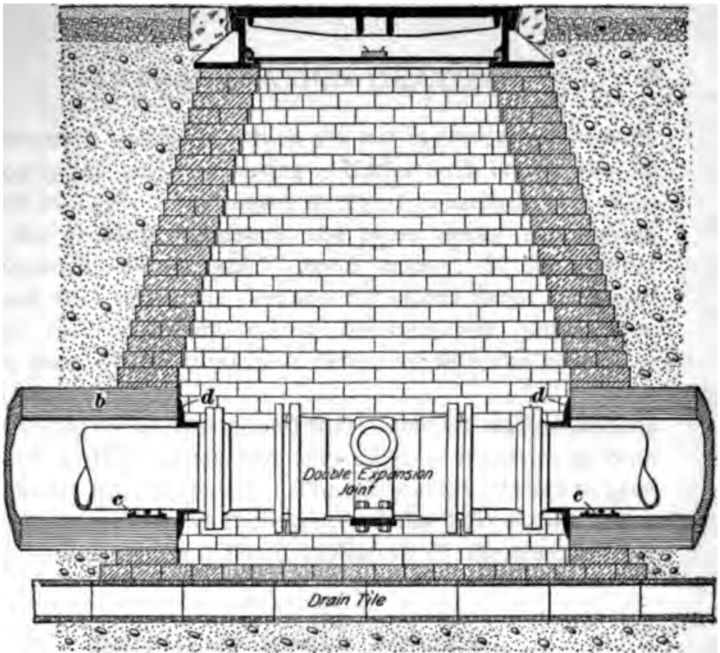
CONDENSATION LOSSES IN STREET MAINS UNDER VARYING DEMANDS FOR STEAM

Rate of Steam Delivery, Compared with Maximum Capacity	Loss in 6-Inch Main, 5,280 Feet Long, in Per Cent. of Total Output	Demand for Steam by Months, in Per Cent. of Total Output per Year
1.00 or maximum	.09	October, 7.09
.90	1.12	November, 10.76
.80	1.41	December, 17.88
.70	1.78	January, 18.62
.60	2.27	February, 17.37
.50	2.03	March, 14.68
.40	3.42	April, 10.31
.30	4.58	May, 3.29
.20	6.76	
.10	10.35	
.05	15.08	

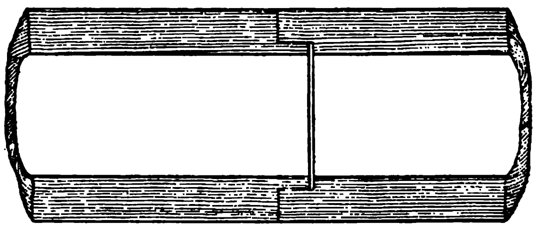
Inasmuch as the total loss of heat from underground steam mains is very nearly constant at all times, it is evident that when the demand for steam is small, as is frequently the case during a large part of the day, the amount of condensation in the mains may at times exceed that which takes place in

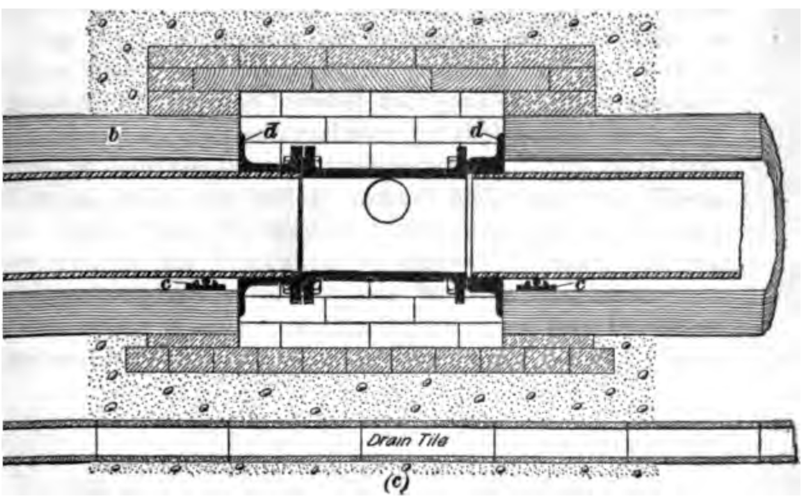


d
d
a
Drain Tile
(a)
b
c
c
Drain Tile
(d)

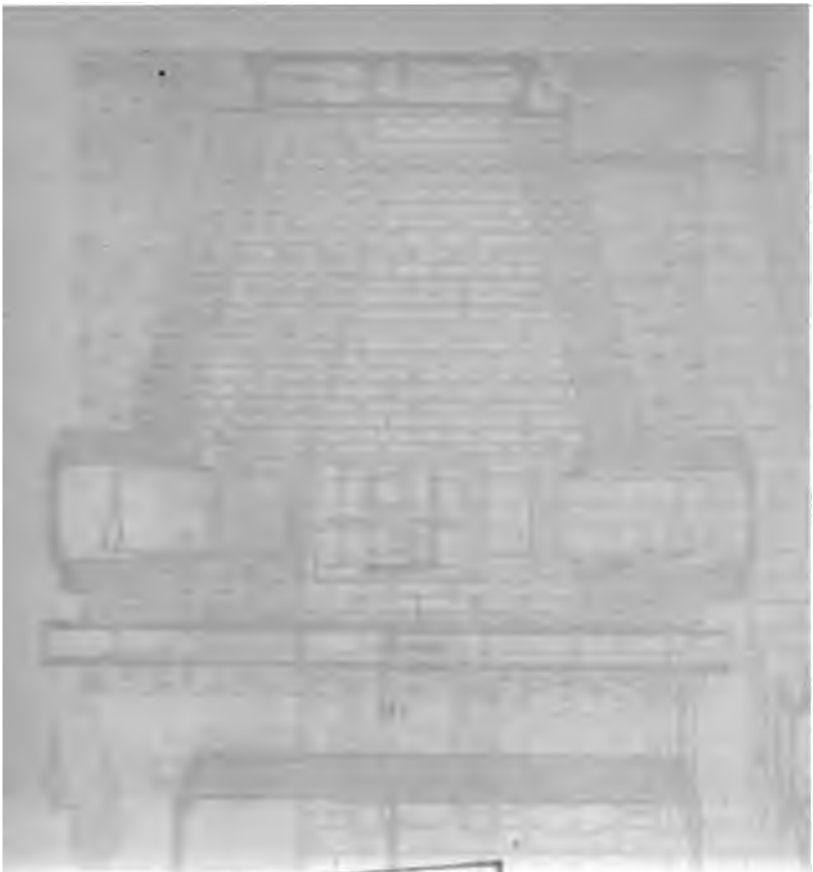


(b)





(c)



the consumers' radiators, which are not in continuous service in the early fall and late spring. Under such conditions, as indicated in Table I, the losses in mains constructed so as to obtain the greatest efficiency, the pipes being surrounded with tin-lined, 4-inch shell wood casing, as hereinafter described, will, when the demand for steam drops to 20 per cent. of the maximum steam consumption, amount to 6.76 per cent. of the total heat delivered into the system at the station.

It must clearly be understood that Table I does not present absolute heat-loss values, but only those of a particular case investigated experimentally. The table is introduced to give an approximate idea of the extent of the heat losses under varying conditions, and the distribution of the demand for steam.

IMPROVED HOLLY SYSTEM

8. The sectional elevation of an underground steam main given in Fig. 1 illustrates the practice and special devices employed by the American District Steam Company, of Lockport, New York, engineers and contractors for the installation of district steam heating plants. The piping is laid in a trench in the street and, wherever it may be necessary, brick manholes, constructed as shown in Fig. 1 (*a*) and (*b*), are placed to give access to shut-off valves, expansion joints, etc. At intervals of 100 feet, the piping is rigidly held in position by means of fittings known as *anchor specials*, shown in Fig. 1 (*c*); to provide for expansion and contraction, a device known as a *double variator*, shown in Fig. 1 (*d*), is placed in the pipe line between each pair of anchor specials. The anchor specials and variators are enclosed in water-tight brick or concrete boxes having 6-inch or 8-inch walls that, when of brick, are laid in cement and plastered. These boxes are filled with insulating material. The devices are anchored in the brickwork by means of heavy cast-iron saddles, and to the wood casing by iron bars, as *a*.

The piping is covered with asbestos paper held by copper wire and is enclosed in round tin-lined wood casing *b* having

a 4-inch thickness of shell, the inside bore of the wood casing being from 2 to $2\frac{1}{2}$ inches larger than the outside diameter of the enclosed pipe. The pipe is carried on and centered by means of guides and rollers *c, c* placed in the casing about 7 feet apart. The space between the pipe and the wood casing is made a dead-air space by means of collars *d, d* and packing placed at intervals of about 50 feet. In order that the wood casing shall not at times be surrounded by water due to infiltration, springs, and leaky water pipes or sewer pipes, underdrainage of the pipe line is provided by laying a 4-inch tile drain at the bottom of the trench, as shown.

PIPES AND FITTINGS

9. The steam-supply piping commonly employed for underground work is of the best quality of wrought iron, the piping having been subjected to a hydraulic test pressure of 500 pounds per square inch before installation; when in actual service it should withstand a steam pressure of 70 pounds without leaking. Steel pipe should under no circumstances be employed for underground work on account of its comparatively short life for such service.

Long, heavy, recessed couplings, made as shown in Fig. 2, are employed in joining underground piping; connection

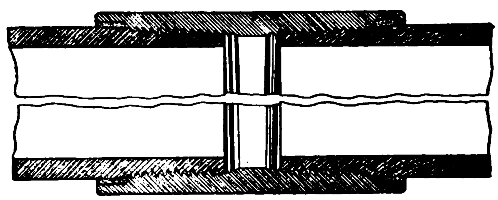


FIG. 2

between valves and special fittings is made by means of flange joints, soft annealed copper gaskets being used between the flanges.

10. Compared with the life of pipes supplying steam, that of mains for returning water of condensation is comparatively short; in fact, the deterioration of return pipes is

so rapid that their use in extensive district systems of heating has been abandoned, other means having been adopted to utilize a part of the heat in the water of condensation, which is discharged through a trap to the sewer instead of being returned to the boilers. With comparatively small private central-heating plants, such as are commonly employed for supplying steam to the various buildings of a state institution, or those used by a large university, it is customary to use a return main, the boiler plant frequently being so located that the water flows, by gravity, to a receiver or is pumped back for feeding the boilers.

11. Recently there have been installed a number of two-pipe systems of considerable magnitude in which the water of condensation is returned to the generating plant through wooden pipe having a 3-inch shell. During the time that the round wooden water pipe has been used to return condensation to the station it has proved entirely satisfactory. No means has to be provided to care for expansion or contraction, and the pipe is self-insulating. Where wooden return mains are installed, provision should be made to keep the mains either full of water or constantly dry, as the life of wood is practically indefinite if it is kept continuously wet or continuously dry. Wooden water pipe is in quite extensive use in many waterworks systems, and has been underground for more than 100 years.

12. In localities where the cost of feedwater is excessive, expensive purification being necessary to make the water fit for use in boilers, a return main may advantageously be used, but ordinarily the value of the water of condensation, if returned to the central station, would not amount to the interest on the investment for the piping necessary to return it. Screw-end cast-iron pipe joined by special cast-iron threaded couplings, instead of the ordinary bell and spigot lead-packed joint, may be used whenever local conditions necessitate the use of a return main.

13. Return mains are sometimes constructed of so-called **Universal pipe and fittings,** which are made of cast iron;

its principal feature, as illustrated by Figs. 3, 4, and 5, is the connection by means of which the pipes and fittings are joined together, making cast-iron pipe available for purposes for which wrought-iron pipe has been used exclusively here-

FIG. 3

tofore. Being made of cast iron, the pipe is especially adapted for use in the ground and for returning the water of condensation, which is more or less destructive to wrought iron. The pipe is made in a variety of sizes from 2 to 8 inches, and to stand pressures of 150, 200, 250, 300, and 400 pounds per square inch, the thickness of the pipe being increased with each diameter. The pipe is provided with bosses *a*, *a*, Figs. 3 and 4, for tapping purposes, placed 36 inches from center to center, the

FIG. 4

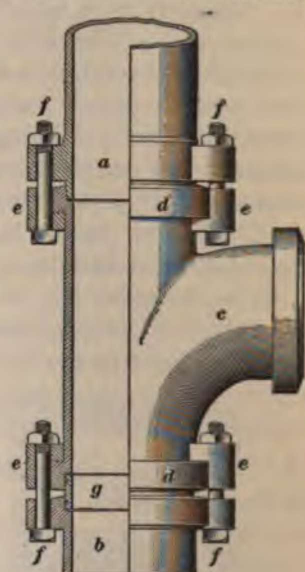


FIG. 5

regular length of the pipe being 6 feet. These bosses provide a thickness of $\frac{5}{8}$ inch at the thinnest point.

In addition to the regular length, the pipe is made in shorter pieces of 60, 54, 48, 42, 36, 30, 24, 18, 12, 9, and 6 inches. Strong lugs *b*, *b*, Fig. 3, are cast on each end of the pipe.

14. The method of connecting the pipe with the fittings is indicated in Fig. 5. The spigot end *a* of the pipe is turned

to a standard taper and size; the hub end *b* of the pipe is bored to the same taper, but slightly smaller. With an iron-to-iron connection afforded by such a machined bearing, there is no necessity for using any joint cement, except to prevent corrosion and thereby obviate trouble in case the joint must be separated. Referring to Fig. 5, it will be noticed that the fitting *c* is provided with flanges *d*, *d* beveled on the under side, and that special castings or loose lugs *e*, *e* grasp these flanges; the bolts *f*, *f* pass through *e*, *e* and serve to draw the joint tight. Fig. 5 also shows the method of connecting two hub ends, the fitting *c* and the pipe *b* being joined by means of a nipple *g*. This nipple is tapered both ways from the center; a shallow groove is turned near each end. The construction permits the pipes and fittings to be connected without being exactly in a straight line, and insures a tight joint if reasonable care is used in making the connections.

Where it is necessary to connect screw-joint wrought-iron pipe with the universal pipe, a special fitting having a tapped end is used. The wrought-iron pipe is screwed in the threaded side of this fitting, and the opposite end, which has a milled face, is bolted to the universal pipe.

15. In laying distributing mains, care must be exercised to secure a uniform grade throughout for proper drainage, the pipe being laid in straight lines between all fixed fittings and variators, or expansion joints. All unavoidable pockets in the line should be freed from water of condensation by means of automatic traps discharging into the sewer. If deemed advisable, the water of condensation at low points may, where practicable, be discharged into the buildings to be heated. Slight deviations from a straight line may be made at the anchor specials, but more abrupt angles must be made by means of angle joints, or with special flanged cast-iron fittings.

16. At the bottom of the trench and beneath the steam main a tile drain should be laid for the purpose of preventing the collection of water around the steam pipes. The tile

should in no case be less than 3 inches in diameter, and it should be so graded as to allow complete discharge of the water. The tile drain must be connected to the city sewerage system or other place of discharge at a sufficient number of points to accomplish the result required, and should be covered to the bottom of the main trench with crushed stone, coarse screened cinders, or gravel. The tile underdrainage system is to be laid at a depth of at least 8 inches below the under side of the insulating wood casing surrounding the steam pipe. In brick-conduit construction, a double line of tile is usually installed.

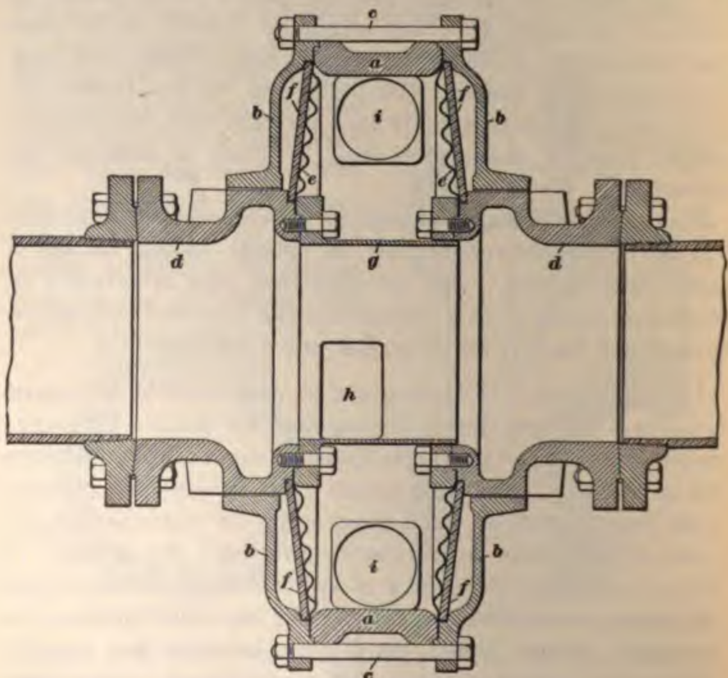


Fig. 6

17. Provision for expansion and contraction of the distributing main is made by employing what are commonly called **variators**, of which two improved styles, the double variator shown in Fig. 6, and the single variator shown in

Fig. 7, are used. The single variator, which has but one diaphragm and one movable end, is used where slight angles, or deviations from a straight line, are desired, changes in direction of the pipe line being effected by the use of wedge-shaped rings. Between the movable end of the single variator and the anchor special the pipe is straight, the angle required for change of grade or alinement being made at the

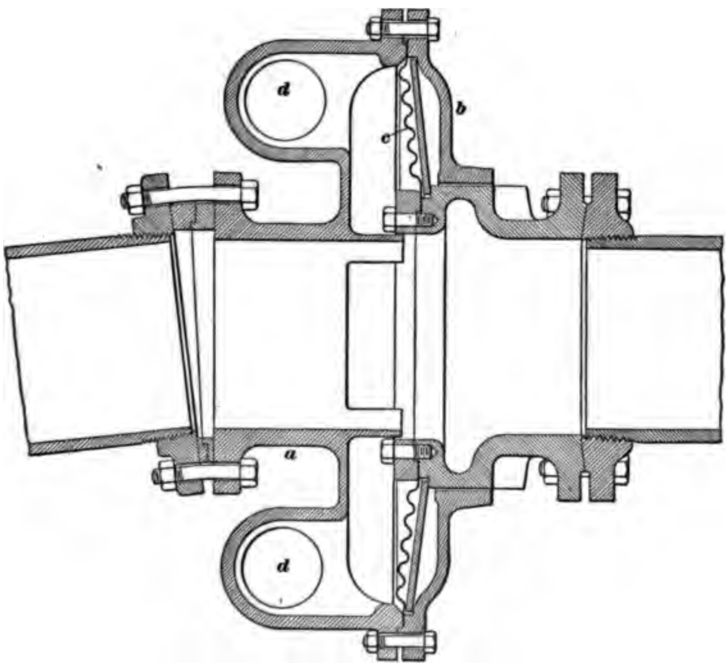


FIG. 7

fixed end of the variator. The double variator is installed only in sections of mains between two fixed points, 100 feet or less apart, and having no offset or deviation from a straight line between the anchor specials that are placed at fixed points.

18. The stationary part, or case, of the double variator consists of a ring-shaped casting *a*, Fig. 6, and two circular heads, or cover-plates, *b*, *b* that are clamped tightly to the casing *a* by means of bolts *c*, *c*. The movable elements

comprise two necks or slips *d*, *d* flexibly connected with the casing by circular copper diaphragms *e*, *e*, so that the slips or necks *d*, *d* can move to and from the casing under the influence of various temperatures. The distributing main is connected with the outer end of each slip, the arrangement of parts of the variator being such as to provide an uninterrupted passage through the two sections of pipe. The two diaphragms *e*, *e* are interposed between the periphery of the necks *d*, *d* and the inner walls of the casing, and are clamped in place in such manner between the parts of the case and the parts of the two slips as to prevent escape of steam. Arranged around the diaphragms are radially disposed plates *f*, *f* that serve not only to reenforce the diaphragms, but also to sustain the necks in such a manner as to permit them to move to and from the case; in order that the diaphragms may not be restricted in the scope of their usefulness they are corrugated, the corrugations yielding in accordance with the various lengths assumed by the pipes. A thimble, or guide, *g* that projects inwardly from the inlet slip is provided to bridge the space between the inner opposed ends of the two necks, or slips, and thus prevent any water of condensation, or what is known as a *slug* of water, from interfering with the operation of the diaphragms. The guide projects beyond the inner terminal end of the outlet slip at a point where the diaghragm is secured in position, so that the flow of steam and water will be carried through the necks, or slips, into the main. One-half of this guide is provided with suitable openings, as *h*, through which steam may pass into the casing. To remove any water of condensation that may accumulate in the pipe line and be carried into the variator case, or to furnish steam to any building, the case is provided with outlets *i*, *i* on each side, into which pipes may be screwed to remove water or to supply steam.

19. The movable half of the single variator, Fig. 7, is identically of the same construction as that of the double variator and performs the same function. The stationary half is a single casting *a* clamped to the cover, or head, *b* of

the variator in such a manner as to securely hold the outer rim of the diaphragm *c*. The stationary half is provided with openings *d*, *d* corresponding to similar openings of the double variator. The variators are anchored by means of bolts passing through brackets secured to the heads *b* on each side.

20. When the parts of the variator are assembled for use, the slips, or necks, are drawn out so that the diaphragms are out of plumb, as shown, to a degree practically equivalent to one-half the extreme expansion to which the pipe will be subjected; hence, when the pipes are expanded to their fullest extent the diaphragms will be practically in the same relative position as before expansion took place, but to the other side.

21. The use of single or double slip joints on underground piping in city streets is objectionable, because they are more likely to leak than the variators and require frequent repacking, to permit of which numerous manholes are necessary, thus increasing the expense of installation. When a brass slip expansion joint is employed, it is installed in the manner indicated in Fig. 1 (*b*), the stationary part of the slip joint being held rigidly in position by being bolted to a saddle embedded in the brickwork of the manhole. Whatever expansion device may be used, it is tapped at its stationary portion to permit service connections being taken from fixed points.

22. The use of offsets for taking care of the expansion and contraction of distributing mains is inadvisable, because of the liability of breaking fittings at bends in large pipe that is too heavy to spring between movable and fixed points. Further, the frictional resistance due to the abrupt turns of offsets decreases the velocity of the flow of steam, causing a loss in the capacity and efficiency of the piping system. The increased length of the pipe due to offsets, accompanied by an increased loss of heat by radiation, together with increased cost of construction in trenching, repaving, etc., are other undesirable features associated with the use of offsets. The use of the latter does not permit making house-service connections at fixed points, and such construction is regarded as being crude in conception and unsatisfactory in operation.

23. For underground use, flanged packingless gate valves with double gates have been found to give very satisfactory service. The type that is provided with a seat on the valve stem is particularly suitable, because when the valve is closed no steam can enter the valve body, and when open the seat on the stem prevents the escape of steam at the gland. The stems of all valves should be provided with square heads of uniform size, so that one socket wrench will fit all valves. The valves are usually bolted directly to flanged crosses and special anchorage fittings, as shown in Fig. 1 (*a*), and are placed within manholes to render them accessible. One of these crosses is placed at each street corner. When the mains at such points are reduced in size, the crosses used have eccentric openings.

24. For the sake of convenience and to save the time that would be required to make special fittings for running pipes at various angles to one another, flanged angle joints, made in adjustable halves, are employed for obtaining any angle up to 90 degrees.

25. **Anchor specials,** shown in Fig. 1 (*c*), are fittings used in the supply mains at anchorage points, from which expansion takes place toward the variators. They are provided with openings for service-pipe connections and are so constructed as to permit of a deviation from a straight line, or change in grade, of 30 inches in a distance of 50 feet. By means of a saddle-and-collar anchorage, the fitting holds the piping securely in position, preventing it from creeping even on a steep grade. Street-corner specials and anchor specials are firmly anchored against the brickwork or the end of the insulating casing by means of cast-iron collars. When necessary, additional anchorage is provided by wrought-iron bars bolted to lugs and securely fastened to the casing by means of not less than four $3\frac{1}{2}$-inch coach screws.

26. Each anchorage fitting, excepting street-corner crosses, placed between expansion devices, is provided with one straight-faced flanged end and one ball-faced flanged end, to allow changes in grade or alinement to be made at

anchorage points. All anchorage devices are tapped for service connections in the same manner as are the expansion devices.

27. Service connections from street mains to buildings are made at anchor specials or variators whose fixed position eliminates danger of a break or leak in the service pipe at the point of connection. The service-pipe openings in the variators and anchor specials are so arranged that connection may be made on either side at the top or bottom of the main.

To insure dry steam being taken into the buildings to be heated, the service connection is made at the top of the fitting from which steam is taken. Whenever it may be necessary or desirable, however, the service connection may be taken from the line fitting at the bottom. Capped nipples of sufficient length to extend through the brickwork for making service connections without disturbing the main trunk-line construction may be installed where deemed desirable, convenient means being employed for protection against corrosion, electrolysis, and loss of heat.

Service mains taken from the top of the street mains are carefully graded upwards from the connection to the building to be heated. When it is desirable to drain the street mains through the service connection, the latter is taken from the bottom of the main, and is laid on a down grade to the building, where it is dripped through a specially designed separator and into a separate trap; the water of condensation is then discharged into the sewer or into an economizing coil.

28. It has been found, in practice, that satisfactory insulation for underground steam piping is provided by covering the iron pipe with asbestos paper $\frac{1}{32}$ inch thick, spirally wound and held in place by No. 19 copper wire, the pipe thus covered being enclosed in round tin-lined wooden casing, as is shown in Fig. 1. The casing is 4 or more inches in thickness, and between the tin lining and the asbestos-covered pipe there is a 2-inch to $2\frac{1}{2}$-inch dead-air space. The casing is

made of carefully selected kiln-dried lumber, dressed into staves, with a groove and tongue running the full length of the stave. The staves are treated with creosote before being placed in a banding machine, wherein they are bound together by means of a $\frac{3}{16}$-inch galvanized-steel wire spirally wound around the casing with sufficient tension to embed the wire in the wood. After being thus bound together, a $3\frac{1}{2}$-inch or 4-inch socket is cut in one end and a corresponding spigot on the other end. The outside of the casing is then thoroughly covered with asphaltum, pitch, and sawdust, and after being tin-lined inside is ready for use. This type of insulation reduces the heat loss by radiation to from .25 to 6 per cent. per mile of pipe at maximum delivery. After installation, the outside of the wood casing is covered with three-ply tar paper extending down to the center line on each side. All fittings, including valves, variators, anchor specials, and crosses, are covered with dry asbestos and soft-wood shavings to a thickness of at least 5 inches previous to the topping off of the enclosing brickwork.

29. The K. and M. sectional conduit shown in Fig. 8 (*a*), which is manufactured especially for use with underground insulation, is made of the same material as vitrified salt-glazed sewer pipe. While in process of manufacture, a cut on a downward slant, as indicated in Fig. 8 (*b*), is made on each side of the pipe, so that, after vitrifying, the pipe may be separated into two parts. To prevent mismating of the parts, which are shipped together, the top and bottom parts of each length are correspondingly numbered on the inside near the end. The trench in which this conduit is laid is usually made about 20 inches wider than the size of the conduit to be employed and of such a depth as to permit of laying, beneath the conduit, an open-joint underdrain surrounded by stones and coarse gravel brought up to the level of the bottom of the conduit.

At intervals where the cement bases, as *a*, for the support of the roll frames, as *b*, are put in, the width of the bottom of the trench is increased enough to allow of filling in with

gravel at the sides of the base, but the drain tile *c* should run under the base *a* as shown. All the drain tile should be laid to the proper grade and should discharge into a large drain or sewer for removing surface water.

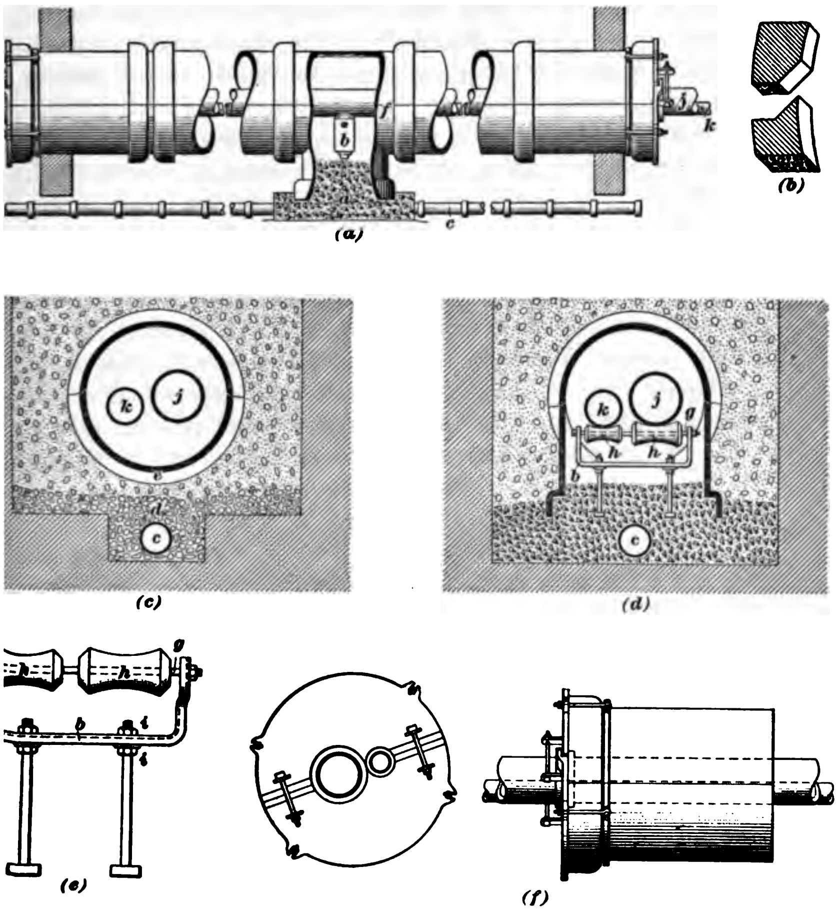


FIG. 8

30. After the coarse gravel *d*, Fig. 8 (*c*), is leveled off on top of the drain tile, the lower section *e* of the conduit is put in place, care being taken to have the edges of the lower section level and the bottom at the proper grade. Each

upper section of the conduit is placed on the bank of the trench opposite the lower section laid in the trench and having the corresponding number. As often as necessary, a **T** *f*, Fig. 8 (*a*) should be laid with the bottom outlet embedded in the cement base *a* that supports the roll frame; the bottom of this section should rest fairly on the gravel. All the ends or sockets should be jointed with Portland cement and be made waterproof.

After the outlet section is in place, and before the cement begins to harden, the roll frames *b*, shown to a large scale in Fig. 8 (*e*), are set with the bolts in place, the whole being supported on the edges, or sides, of the conduit with wedges to hold the frames in the proper position until the cement hardens. When the frames and bolts are in place, the cement is poured in until it is within an inch of the bottom of the frame, when it is smoothed off and the whole is allowed to harden at least 12 hours, when the rod *g* and rolls *h*, *h* can be put in place and any necessary adjustment to level up the rolls can be made by means of the adjusting nuts *i*, *i* above and below the frame. The conduit is then ready to receive the supply pipe *j* and return pipe *k*, which can be made up in the trench if desired, but the roll frames should be wedged or braced until after the testing is completed, and while making up the joints the pipe should be kept away from the rolls.

31. After the steam piping has been tested, the insulating material is filled into the lower section of the conduit, and then a thin mortar of Portland cement is put on the edges of the lower section, and the upper or corresponding half of the conduit is put in place. Cement mortar is then filled in around the socket, and both end and side joints are finished with Portland cement. When the top is in place, the conduit is packed full of the insulating material from the end, care being taken not to disturb the joints. Each upper section is laid in succession until the line of conduit is complete, when shutters are fitted over the ends of the conduit, as shown in Fig. 8 (*f*).

32. For low-pressure steam, the insulation provided may be granulated cork coated with infusorial earth; while for high-pressure steam systems, asbestos filling is recommended by some engineers. The whole space not filled by pipes should be filled with it. The pipes should not be nearer than 3 inches to the sides of the conduit. Hence, for a 5-inch steam pipe with a 2½-inch return pipe in the same conduit, a 15-inch conduit should be used, which will allow 1 inch space between the supply pipe and the return pipe, and 3 inches between the pipes and the conduit on each side.

As soon as the run is completed and the joints have hardened, the conduit is ready to be buried, but coarse gravel should first be filled in well up the sides of the conduit. Where the condition of the ground is such that there will be some settling of the pipe line after installation, the use of a protecting sewer-pipe jacket is not advisable, because breaks or cracks destroy the protective properties of such protection, which, under the most favorable circumstances, is not as durable as the wooden, tin-lined casing usually employed.

CONDUIT CONSTRUCTION

33. It is customary to install 16-inch and larger mains in brick conduits having not less than 8-inch side walls with 4-inch plank covering, bricked over on top, or arched, and built in the same manner and of the same class of material as the brick boxes covering variators and anchor specials shown in Fig. 1. The pipe is supported in the conduit on brick or concrete piers, capped with heavy cast-iron saddles carrying rollers or balls on which the pipe rests, thus permitting free longitudinal movement of the pipe. Concrete conduits having 4-inch or 6-inch walls and tops of concrete and expanded metal are frequently used in place of conduits of brick construction.

34. Conduits are sometimes constructed as shown in Fig. 9, the top of the conduit being covered by stone flagging *a* resting on brick side walls *b*, *b* in which are embedded the iron rods *c* that serve to support the piping,

the movement of which is facilitated by the use of rollers slipped over the iron rods and held apart by distance pieces *d* made of short pieces of pipe one size larger than the rod, washers being placed between the walls and the distance pieces or roller ends. After being laid, the piping is covered with a good quality of pipe covering.

35. The variators, anchor specials, angle joints, and special fittings are usually enclosed in hard-burned brick manholes having not less than 8-inch side walls carefully laid with cement mortar and, as far as possible, made water-tight, being plastered inside and out with cement. Under

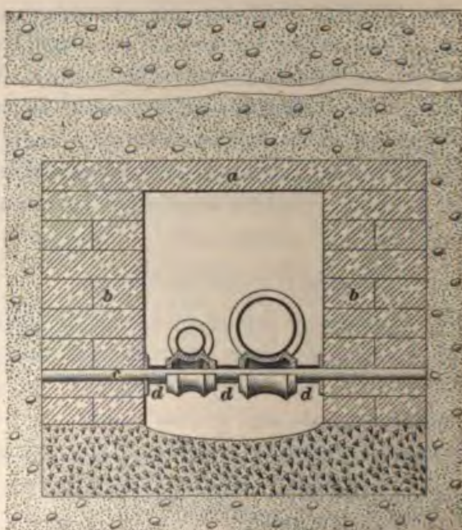


FIG. 9

these boxes there is laid a bottom course or floor of brick, well embedded in cement mortar; the top of the box is usually covered with 4-inch planks. This lumber has a 3-inch bearing all around the top of the box, the ends and sides of the planks being built in with the brick. The top should also be covered with three-ply tar felt, and on top of the plank and tar felt a layer of brick should be laid and thoroughly grouted.

36. All manholes have cast-iron, double-cover manhole curbs, one of which is shown in Fig. 10, the inside cover being so packed as to prevent water from getting in from the street surface. The covers should be round and of sufficient strength to safely carry a load of 5 tons. Where there is but one valve in a manhole, the inside diameter of the manhole opening is never made less than 18 inches. Where there is more than one valve in the same manhole, the inside diameter of the opening is made such that extension wrenches can be put down through the manhole to manipulate the valves, thus making it unnecessary to enter the manhole for that purpose.

37. When a number of detached buildings grouped reasonably close together are to be heated from a central plant, the large distributing mains may be placed profitably in a tunnel large enough for a man to stand in upright.

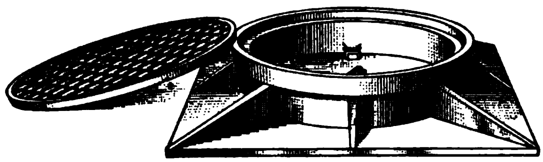


FIG. 10

The loss of heat from the piping therein may be partly recovered by drawing through the tunnel the air supply for the boiler furnaces.

Much expense may often be avoided by running the steam pipes through tunnels of such a size as to facilitate making repairs or replacing pipes. Ordinarily a tunnel 4 feet wide by 4 feet high from footing to spring of the arch, as shown in Fig. 11, is sufficiently large. The tunnel should be constructed of hard-burned brick laid in seven parts of lime mortar to three parts of Portland cement. In damp localities, tile drain connected with the sewer should be run about 8 inches below the bottom of the tunnel and parallel with it. The foundation for the 8-inch wall on each side of the tunnel consists of a footing 12 inches wide and 6 inches high. The side walls, as well as the arch, should be well cemented on

the outside, making them as nearly water-tight as possible. At points 10 feet apart on each side of the tunnel, a pier is constructed for supporting a bearing for a channel iron *a* resting on bearing plates *b*, *b*, as shown in Fig. 11. Eighteen inches from each end a 1-inch hole is punched in the channel iron to receive a rod *c* or piece of small pipe having a long thread and a deep nut for adjustment. This rod or pipe extends into the tunnel through a short piece of 3-inch gas

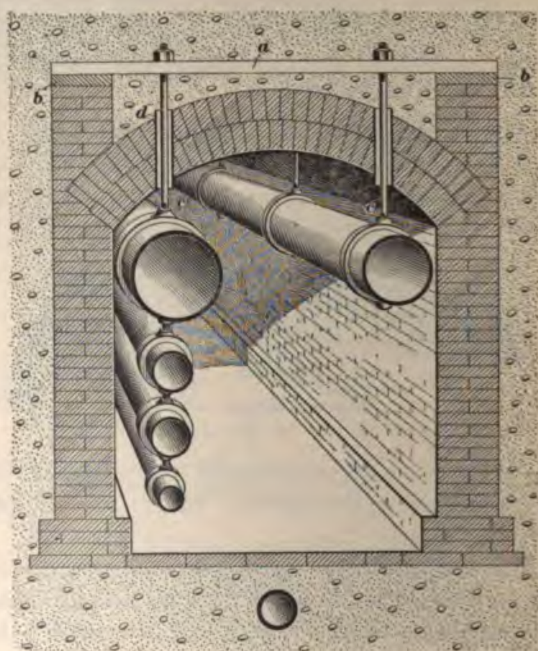


FIG. 11

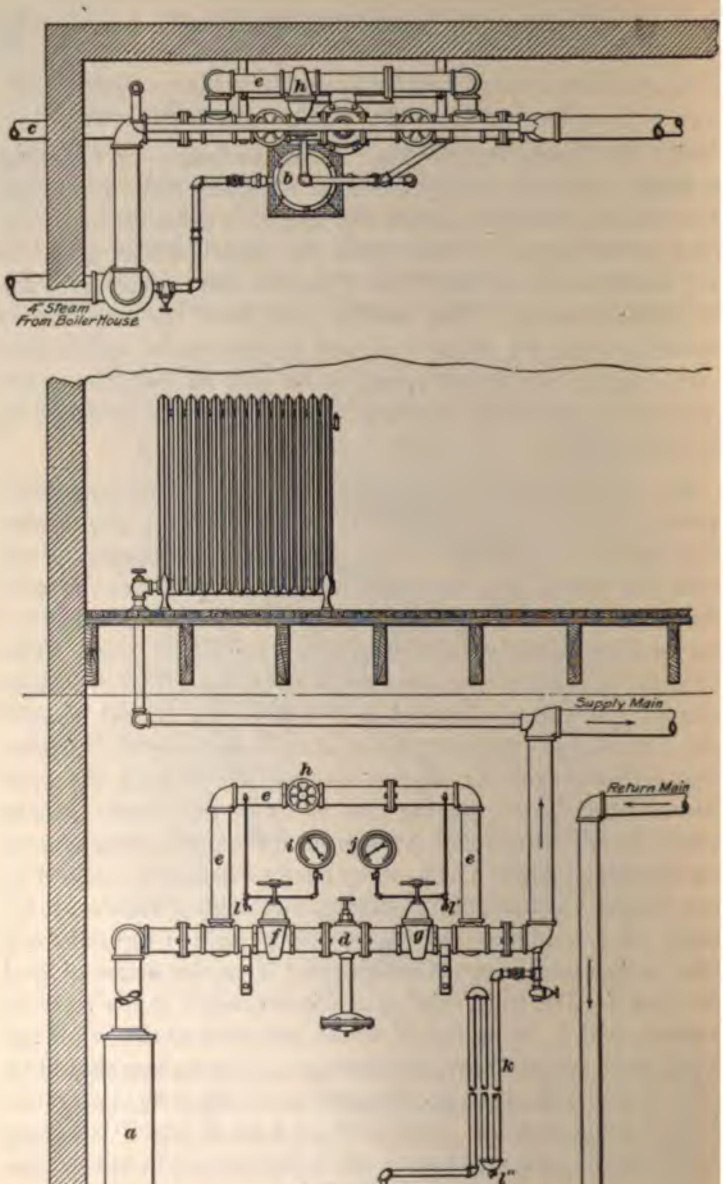
pipe *d* firmly embedded in the arch in an upright position, and connects with rings slipped over the steam piping, as shown. Three or four pipes may be easily supported from the same rod by placing two rings over the pipe at each point of support, the tapped openings in one ring being turned downwards to permit connection with a similar ring on the pipe below.

INDOOR DISTRIBUTING SYSTEM

38. Pressure-Reducing Connections.—In heating buildings with low-pressure steam received from high-pressure mains under the streets, the use of a pressure-reducing valve is necessary in order that the street steam pressure may be reduced to, say, 2 or 3 pounds per square inch for indoor distribution. The service pipe from the street main passes through the cellar wall, and just inside the wall a gate valve is placed to permit steam to be shut off from the whole building, the pressure-reducing valve being next attached to the service pipe.

39. Fig. 12 shows an approved method of making pressure-reducing valve connections. Steam from the street main enters a large pipe *a* that serves as a separator, from which the water of condensation flows to the return trap *b*. The latter discharges into the low-pressure return main *c* that empties into a receiving tank in the boiler room. The pressure in the heating system is controlled by a pressure-reducing valve *d* around which is arranged a valved by-pass pipe *e*, so that the reducing valve *d* may be repaired, if necessary, without shutting off the steam. By closing the gate valves *f* and *g* and opening the valve *h*, the steam passes around the reducing valve *d*; the pressure in the heating system may then be controlled by hand by partly closing the valve *h* so as to throttle the supply of steam. A high-pressure steam gauge *i* is provided on the high-pressure side of the reducing valve; a low-pressure steam gauge *j* is on the house side of the valve *d*. The relief piping at *k* is arranged in the form of a siphon, which, being full of water, prevents steam from the supply main entering the return main *c*. The siphon should be made of such a depth as to offset any probable drop in pressure in the heating system. Draw-off cocks l, l', and l'' are provided to drain the water seals when the system is not in use.

40. When the use of reducing valves is necessary, in order to vary the pressure carried on the heating system in each of several buildings supplied by a central heating plant,



c
e
h
b
4" Steam
From Boiler House
Supply Main
Return Main
h
e
e
e
i
j
l'
l'
f
d
g
k
a
l''
c
b

Fig. 12

to which the water of condensation is to be returned, it is necessary to use a steam trap through which to discharge the condensation from the heating system into a main return connected with a closed receiving tank. If the pressure in any one of several buildings is much in excess of that in others from which the water of condensation is discharged into a receiving tank in the boiler room, it will be necessary to use traps on the returns from buildings in which the comparatively low pressure may be carried.

41. Cooling, or Economizing, Coils.—The use of a return main having been abandoned in many district steam heating plants, the water of condensation from the radiating surface in each building, before being discharged to the sewer, is passed through what is known as a **cooling,** or **economizing, coil,** by means of which a part of the heat that would otherwise be lost is utilized in warming fresh air. In passing over the coil, the fresh air lowers the temperature of the water of condensation to such an extent that it may be discharged without injury to the sewer.

Water of condensation should not be discharged into the sewer at a temperature higher than 120° F. It should never be discharged into a drainage system on the house side of the main disconnecting trap, because the hot vapor from the water of condensation will soon ruin the plumbing system.

42. Referring to Fig. 13, which shows an approved arrangement of the economizing coil and steam trap, combined with auxiliary indirect heating surface, the water of condensation flows through the return pipe *a* into the trap *b* and thence through the pipe *c* into the lower coil *d*, through which it passes in the direction of the arrows to the upper coil *e*, and out through the pipe *f* to a meter that registers the amount of water discharged from the meter to the sewer. From the supply main in the cellar, steam flows to the pin-type indirect radiator *i* through a branch pipe *j*, while the water of condensation passes through the valved connection at *k* directly into the trap, to the top of which an air-vent connection *l* is made, a similar connection *m* being provided

for the indirect radiation. It will be noticed that provision for breaking any of the connections has been made by the use of unions, permitting any part of the combination to be separated from the other parts. The economizing coil, trap, and indirect radiator are enclosed in a tin-lined chamber to

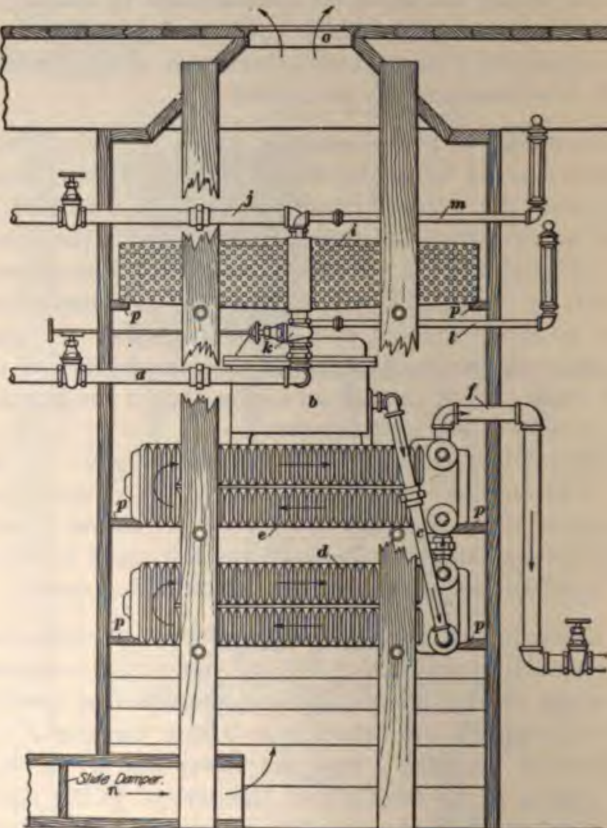


FIG. 13

which fresh air is delivered by the duct *n* and from which the warmed air passes through the register *o* into the hall or room above. As the cold air first comes in contact with the surface of the economizing coil, much of the heat in the water of condensation therein is extracted and the water is cooled

to a temperature at which it may pass into the sewer without harmful effect. Air stops *p*, *p* prevent the air from passing around the ends and sides of the cooling coils and indirect radiation. Besides utilizing the heat that would otherwise be lost, the indicated use of the economizing coil as indirect heating surface has the advantage of providing ventilation where it would not otherwise be provided. The use of an economizing coil in the manner shown effects a reduction of about 10 to 20 per cent. in the amount of steam that would otherwise be required to heat the building.

43. The amount of cooling surface required in the economizing coil depends on the amount of radiation served and the temperature at which the water of condensation is to be discharged into the sewer. With the economizing-coil arrangement shown in Fig. 13, the proper surface, in square feet, of the coil may be determined by using Table II.

TABLE II

ECONOMIZING COIL FACTORS

Temperature of Water Discharged by Trap Degrees	For Size of Economizing Coil, in Square Feet Multiply Direct Radiating urface by
80	.140
100	.100
120	.084
140	.066
160	.050

For example, for 400 square feet of direct radiation and a condensation temperature of 100° the required cooling surface in the economizing coil will be $400 \times .1 = 40$ square feet; while for a condensation temperature of 160°, the required cooling surface will be only $400 \times .05 = 20$ square feet.

44. Steam-Trap Capacity.—In Table III is given the approximate amount of radiation from which ordinary types of steam traps, such as are used with economizing coils, will

freely discharge the water of condensation at pressures ranging from 5 to 10 pounds per square inch.

45. Condensation Meters.—As a reliable means of determining the amount of steam used by individual consumers, special meters are provided for measuring the amount of condensation from the radiating surface in each building, the monthly charge for steam being in accord with registration of the meter, which gives the amount of condensation, in pounds.

TABLE III

APPROXIMATE CAPACITY OF STEAM TRAPS

Size of Trap Outlet Inches	Amount of Direct Radiating Surface Trap Will Drain, in Square Feet	
	Direct	Indirect
$\frac{1}{2}$	1,200	800
$\frac{3}{4}$	2,200	1,400
1	3,400	2,200
$1\frac{1}{4}$	4,800	3,100
$1\frac{1}{2}$	6,800	4,400

46. Piping Systems.—Any of the common methods of piping buildings may be employed for the indoor distribution of steam supplied by a central station. Equally good results are obtained with single, double, drop, and other systems of piping when properly proportioned, but when the available pressure is greater than would ordinarily be generated in an isolated private plant designed for heating the same building, the piping throughout may be made somewhat smaller. As a matter of fact, smaller piping than would otherwise be used may be put into a building to be heated by steam derived from a source outside the building, because the distance between the lowest point in the supply main and the return connection, or inlet to the steam trap, may be made greater than the corresponding distance between the lowest point in the supply main and the boiler water-line of

a private plant. The water-line of a heating system supplied with steam from a central station corresponds to the position of the inlet opening of the steam trap, which may be lowered sufficiently to obtain any desired drop in pressure, the adopted size of piping corresponding to the chosen drop in pressure.

Recently there has been introduced a new system of house piping in which top-connected radiators are installed and steam supplied at very low pressure through specially constructed valves that are designed to permit the use of as much of each radiator as is desired; that portion of the radiator not filled with steam (being the lower part) acts as economizing radiation and by extracting the heat in the water of condensation practically all the heat originally contained in the steam when delivered to the radiator is utilized.

Private hot-water heating plants may readily be adapted to the use of steam supplied from a central station through the use of a steam-heated hot-water boiler.

47. Temperature Regulation.—In connection with the distribution of steam from a central heating plant, automatic regulation of the temperature in the buildings supplied is usually accomplished by placing in each building one or more thermostats, by the action of which compressed air is admitted to or released from the shut-off valves. Not only is the temperature of the building thus regulated, but a material saving of steam is effected.

RATES FOR HEATING

48. There is considerable variation in the rates charged for central-station heating in different cities, the conditions controlling the price charged being the cost of fuel, the distance the service is carried, the range of external temperature, the humidity and wind velocity, and the duration of the heating season. In some localities, a flat rate (that is, a fixed amount) per season is in vogue; while in others the meter rate has been adopted, the charge for steam being based on the amount of condensation that passes through the meter in a given time, usually a month of $4\frac{1}{2}$ weeks. With some

companies, the meter rate varies with the amount of steam used, the charges per 1,000 pounds of condensation becoming less as the amount of steam used becomes greater. Charges for steam heating are sometimes based on a fixed rate per square foot of radiation, or per 1,000 cubic feet of space heated (outside measurement).

Heating companies at present favor the use of a meter that measures the condensation from the various radiators and pipes throughout the building. For this condensation a price, usually about one-tenth the cost per ton of anthracite, is made for each 1,000 pounds of condensation measured, on which basis it is assumed that the maximum efficiency of an ordinary isolated private heating plant would be an evaporation of 5 pounds of water per pound of fuel, in which case a ton of fuel would produce 10,000 pounds of steam.

The method of charging customers for steam on the basis of the square feet of radiation installed is somewhat unsatisfactory, because of the fact that the ratio of radiation to the amount of space heated varies greatly, depending largely on the pressure, construction of the building, individual temperament, and economical use of steam by the customer.

49. As the actual amount of radiation in use in a house is constantly being changed, the only basis of charge equitable to the customer and the company alike is the amount of steam consumed, as shown by the condensation meter. There are very decided differences in the amount of steam required by various customers and in various buildings, due to differences in the amount of glass and wall exposure, height of ceilings, and manner in which the customer uses steam. The amount of steam consumed also varies with the outside temperature and is most decidedly influenced by the humidity and by the velocity of the wind.

SIZE OF DISTRIBUTING MAINS

50. The size of the mains through which steam from a central station is distributed depends on the pressure and the distance that the steam is to be carried. Supply mains are usually installed to provide for future increases in the demand

for steam, so that no generally applicable rule for determining their sizes can be given. For comparatively small installations, however, the proper area of distributing pipes, in square inches, may be calculated approximately by multiplying the amount of radiation, in square feet, to be supplied, by the factors given in Table IV. The pipe sizes obtained by the use of the factors presented are the sizes required for a gravity system of heating at pressures ranging from 2 to 10 pounds, as well as the sizes that will give good results with the Paul and Webster systems of heating at or below the pressure of the atmosphere.

The required area of service-pipe connections may be obtained by multiplying the number of square feet of radiation to be supplied by .0012, if the service pipes do not exceed 50 feet in length and if the pressure does not drop below 10 pounds in the mains; otherwise, the service pipes should be made one or two sizes larger. If the amount of radiation is less than 1,000 square feet, the service pipe should be increased one size. No service pipe smaller than 1¼ inches should be used.

TABLE IV

FACTORS FOR AREA OF DISTRIBUTING MAINS, IN SQUARE INCHES

Gauge Pressure in Mains Pounds per Square Inch	Length of Distributing Main, in Feet							
	100	200	400	600	800	1,000	1,200	1,500
	Factors							
0, with Paul or Webster system	.0025	.00323	.00375	.00397	.00412	.00420	.00423	.00425
2	.0040	.00516	.00600	.00636	.00660	.00672	.00676	.00680
5 to 10	.0030	.00387	.00450	.00477	.00495	.00504	.00507	.00510

EXAMPLE.—What should be the size of a distributing main intended to supply 12,000 square feet of radiation, the main being 1,400 feet long and the steam pressure averaging 6 pounds per square inch?

SOLUTION.—Referring to Table IV, the factor nearest to 1,400 ft. is .0051. Then, 12,000 × .0051 = 61.2 sq. in. area. The nearest standard size of pipe is 9 in., which has an internal area of 63.6 sq. in. Ans.

EXAMPLE OF A CENTRAL-STATION STEAM-HEATING SYSTEM

51. Fig. 14 shows, in plan, a small central-station steam-heating installation. From the boiler house and engine

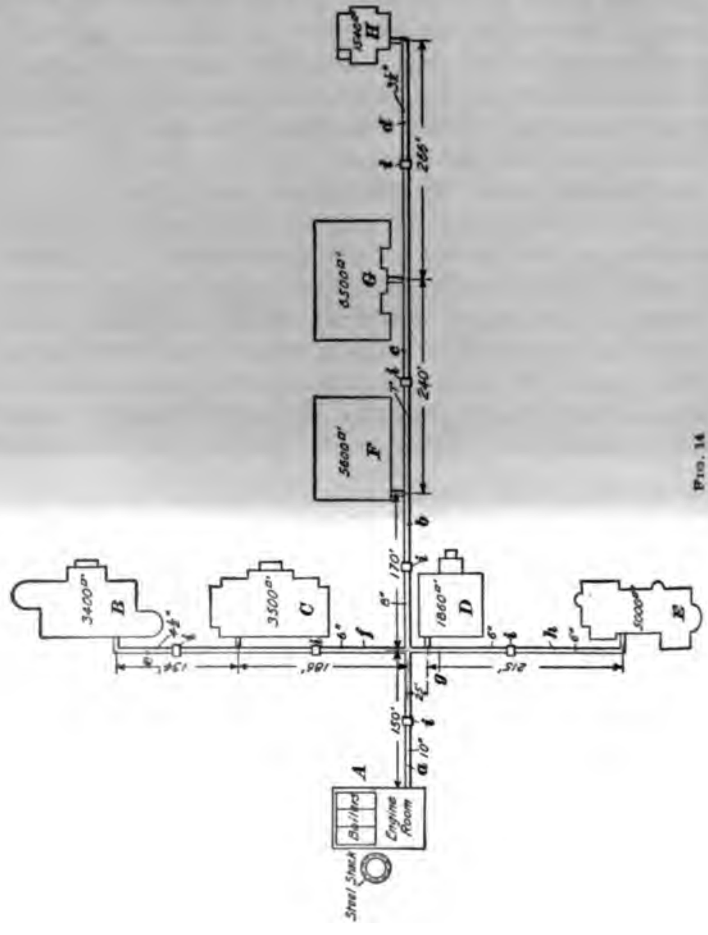


FIG. 14

room *A* light, heat, and power is furnished to the buildings *B*, *C*, *D*, *E*, *F*, *G*, and *H*. The amount of direct radiation required to heat each building is shown in the figure;

thus, the building *F* contains 5,600 square feet. The boilers generate steam for dynamos located in the engine room. These dynamos generate electricity for lighting the buildings and the institution grounds, and also produce the electric current for the elevator motors and power machines employed throughout the institution. The exhaust steam from the engines is turned into the steam-heating mains, and if this is not enough to supply the requirements of the radiation, the surplus is provided in the ordinary manner directly from the boilers through a pressure-reducing valve.

In order to use the exhaust steam, it is necessary to have a low pressure in the mains; therefore, it is advisable to equip the buildings with vacuum steam-heating systems, such as the Paul or Webster system. This will reduce the sizes of the mains to a minimum, which will materially reduce the cost of the underground system.

If the boilers are located below the level of the lowest building, the mains will pitch up toward the buildings and must be drained at each service connection. In such a case the condensation from all the buildings can flow by gravity, if necessary, back to a hotwell in the boiler room, from which receptacle it may be pumped back to the boilers. If the mains pitch down from the boilers to the buildings, the mains may be drained either through the service connections or by a steam trap located at each of the lowest ends.

If vacuum systems of heating are employed in the buildings, the vacuum pumps in the buildings can pump the condensation water back to the boiler-room hotwell independently of the pitch of the mains, or into the sewer through cooling coils, as desired.

52. The sizes of the mains in Fig. 14, as marked, are calculated from Table IV on the assumption that a pressure of from 5 to 10 pounds per square inch is maintained in the main at the engine room and that gravity-return systems are used in the buildings. During moderately cold weather, the pressure in the mains may be approximately 5 pounds above that of the atmosphere, but during very

cold weather, when a large volume of steam must flow through the mains, the pressure will probably rise to about 8 or 10 pounds above that of the atmosphere.

53. Table V shows the sizes of the pipes that would be used for the underground mains shown in Fig. 14 with different heating systems in the buildings. With a low-pressure heating system in the buildings and a pressure of from 5 to 10 pounds in the mains, the steam pipe *a* may be 10 inches

TABLE V

SIZES OF MAINS IN FIG. 14

Line of Piping in Fig. 14	Low-Pressure Systems				Vacuum Systems				
	Steam at 5 to 10 Pounds Pressure		Steam at 2 Pounds Pressure		Paul System Atmospheric Pressure			Webster Vacuum System	
	Steam Pipe Inches	Return Pipe Inches	Steam Pipe Inches	Return Pipe Inches	Steam Pipe Inches	Return Pipe Inches	Air Line Inches	Steam Pipe Inches	Return Pipe Inches
a	10	5	12	6	9	$3\frac{1}{2}$	1	9	3
b	8	4	10	5	7	2	1	7	2
c	7	4	9	$4\frac{1}{2}$	6	2	1	6	2
d	$3\frac{1}{2}$	3	$4\frac{1}{2}$	$3\frac{1}{2}$	3	$1\frac{1}{2}$	$\frac{3}{4}$	3	$1\frac{1}{4}$
e	$4\frac{1}{2}$	$3\frac{1}{2}$	5	$3\frac{1}{2}$	4	2	$\frac{3}{4}$	4	$1\frac{1}{4}$
f	6	$3\frac{1}{2}$	7	4	5	2	$\frac{3}{4}$	5	$1\frac{1}{2}$
g	6	$3\frac{1}{2}$	7	4	5	2	$\frac{3}{4}$	5	$1\frac{1}{2}$
h	6	$3\frac{1}{2}$	7	4	5	2	$\frac{3}{4}$	5	$1\frac{1}{2}$

in diameter and its corresponding return main, which is not shown, may be 5 inches in diameter. If the pressure in the steam main at the engine house does not exceed 2 pounds and if the heating systems in the buildings are of the low-pressure gravity type, the size of the pipe line *a* should be

12 inches and its corresponding return main 6 inches. In the same table, it will be seen that the steam main *a* for either a Webster or a Paul system should be 9 inches and the corresponding return mains about 3 or $3\frac{1}{2}$ inches.

The sizes of the different pipes *b*, *c*, *d*, *e*, *f*, *g*, and *h* of the underground lines are also given in the table. This table emphasizes the economy in installation that can be secured by installing vacuum systems in the buildings instead of low-pressure systems. The expansion joints along the lines are shown at *i*. The lines are anchored at the service connections shown running into the buildings.

HOT-WATER HEATING PLANTS

THE CENTRAL STATION

GENERAL INFORMATION

54. When power or lighting stations are combined with a central hot-water heating plant, the exhaust steam from the engines of the power or lighting station is used to heat the water in the hot-water heating plant. The hot water is forced by a pump, located at the station, through the mains, through the piping systems and radiators in the buildings to be heated, and then back to the station, where it is reheated and again circulated through the buildings. Thus the water is used only as a medium to convey the heat of the exhaust steam from the engines to the radiators in the several buildings.

55. Cheapness of installation is one of the advantages claimed for the district hot-water heating system, it being unnecessary to use as many expansion joints as are required with the steam system. To some extent, however, the advantage in having fewer expansion joints is offset by the necessity for a return line of the same size as the supply main. The temperature of the water mains being lower and the heat transmission by conduction to water outside the

mains being less rapid, subdrainage is considered unnecessary with the hot-water system. The heat loss from the underground mains is much less than with steam. For residence heating, the hot-water system is favored because of the low temperature of the radiating surface. With the hot-water system, there is no waste of water at low points in the distributing mains nor from each building to the sewer; hence, there is no loss of heat at these points. Among other advantages claimed for the hot-water system are ready regulation of temperature, the possibility of using water for storing the heat of exhaust steam that otherwise would be wasted, the operation of engines without excessive back pressure, the absence of offensive odors from air valves, and easy location of serious losses of water.

56. Central-station hot-water heating plants are usually installed in connection with electric lighting and power plants in order to utilize the heat in exhaust steam that would otherwise be wasted. The exhaust steam passes into closed heaters of large capacity, the water being circulated through the heater and distributing pipes by means of pumps. The outlet of the heater may or may not be provided with a back-pressure valve, according to the condition under which the plant is operated. As a rule, however, no back pressure on the engines should be necessary. Live steam may be admitted to the heaters through a reducing valve when the supply of exhaust steam is insufficient, or auxiliary boilers may be employed for generating steam at low pressure or for merely heating water to be discharged directly into the mains.

57. The amount of exhaust steam available should determine the extent of a district hot-water heating system. Except to provide for extremely cold weather conditions and to obviate lack of heat in case of accident to engines furnishing exhaust steam, the use of auxiliary heating apparatus should not be necessary in a properly designed plant, which should not be of greater extent than required to absorb all the heat in the exhaust steam available.

The amount of exhaust steam available for heating purposes is about 20 per cent. less than the amount of live steam delivered to the engine cylinder; in other words, 80 per cent. of the steam consumed by the engine is available for heating purposes. Hence, in a plant wherein the steam consumption per horsepower hour is, say, 30 pounds, there would be available for heating $.80 \times 30 = 24$ pounds, which would be sufficient steam for heating the water supply to 140 square feet of direct radiation in ordinary winter weather.

No effective means has yet been found for storing any considerable amount of the heat of surplus exhaust steam delivered by the engines at times when the demand for power is at a maximum for use at times when there is a maximum demand for heat. The storage tank sometimes employed is provided solely for the purpose of absorbing heat when the supply of exhaust steam is excessive, as at times when the electric load is heavy.

INSTALLATION AND OPERATION

58. In what are known as open-circuit systems, that is, systems in which the pump takes its supply from an open tank, the pressure on the outgoing supply main at the station may be as high as 60 pounds per square inch, depending on the head, or pressure, against which the pump works, the head corresponding to the height of the highest radiator above the pump, plus the pressure necessary to overcome friction in the piping.

With closed-circuit or balanced-column systems, that is, systems in which the pump takes its supply direct from the return main, the differential or circulating pressure varies from 10 to 30 pounds, depending on the frictional resistance of the piping.

59. The velocity with which the water in the system is circulated may be varied to suit the requirements of the weather, the amount of water supplied per square foot of radiating surface per hour varying from 6 to 18 pounds, depending on the temperature drop and emissive capacity

of the radiation. The following table gives the approximate flow of water necessary per square foot of radiating surface per hour at various temperature differences:

TABLE VI

FLOW OF WATER REQUIRED PER SQUARE FOOT OF RADIATING SURFACE PER HOUR

Temperature Difference Between Flow and Return Pipes Degrees Fahrenheit	Temperature Difference Between Air in Room and Water in Radiator Degrees Fahrenheit		
	90	100	110
	Flow of Water Required per Square Foot of Radiating Surface per Hour, in Pounds		
10	16.00	17.00	18.00
12	13.30	14.20	15.00
14	11.40	12.10	12.80
16	10.00	10.60	11.30
18	8.88	9.42	9.96
20	8.04	8.46	8.94

60. To meet the conditions imposed by extremely cold and high winds some engineers install sufficient radiation to maintain an internal temperature of 70° with an external temperature of 20° below zero. When thus proportioned, the central station is called on to supply, on an average, water for but 40 per cent. of the maximum amount of radiation installed, the requirements throughout the season seldom exceeding this percentage.

The amount of direct radiation that should be installed in buildings of ordinary construction and exposure, in order to meet extremely cold weather requirements with a comparatively low temperature of the circulating water, may be found by the following:

Rule.—*Divide the number of square feet of exposed wall surface by 10, and the cubical contents, in cubic feet, by 100; add*

the exposed glass surface, in square feet, to the quotients; the sum thus obtained will be the number of square feet of direct radiating surface required for the building.

Or,
$$R = \frac{W}{10} + \frac{V}{100} + G$$

where R = direct radiation, in square feet;
W = exposed wall surface, in square feet;
V = volume of building, in cubic feet;
G = exposed glass surface, in square feet.

The amount of radiation computed by the rule just given is about 50 per cent. more than is installed for ordinary hot-water heating systems furnished with individual boilers. This excess of radiation will offset a low temperature in the street mains, such as is liable to occur during cold weather.

EXAMPLE.—A dwelling house has 22 windows measuring 2 feet 9 inches by 6 feet; the total wall surface is 3,040 square feet, and the cubical contents are 28,560 cubic feet. How much direct radiation is required?

SOLUTION.—Since 2 ft. 9 in. = $2\frac{3}{4}$ ft., the exposed glass surface is $2\frac{3}{4} \times 6 \times 22 = 363$ sq. ft., and the exposed wall surface $3{,}040 - 363 = 2{,}677$ sq. ft. Applying the rule given,

$$R = \frac{2{,}677}{10} + \frac{28{,}560}{100} + 363 = 916.3 \text{ sq. ft. Ans.}$$

61. For controlling the amount of water supplied to each building, it is customary to insert what is known as a **choker** in the return line of the house circuit. This choker may be a short piece of small pipe inserted between two reducers in the return line, as indicated in Fig. 15, or it may be a per-

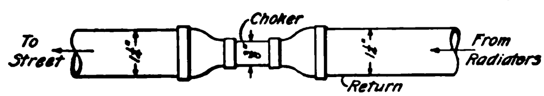


FIG. 15

forated disk inserted in a union coupling in the return line. Whichever method is adopted, the size of the choker opening for supplying a given amount of radiation at a given temperature drop is governed by the difference in the pressure on opposite sides of the disk. Table VII gives the approximate amounts of direct radiation that may be

supplied through chokers of various sizes with a pressure difference of 5 pounds and with different temperature drops. The capacity of chokers at pressure differences other than 5 pounds may be found by multiplying the quantities in Table VII by the factor, corresponding to the pressure difference, taken from Table VIII.

TABLE VII

DIRECT RADIATION SUPPLIED THROUGH CHOKERS

Size of Choker Opening Inches	Temperature Difference Between Main Flow and Return Pipes Degrees Fahrenheit										
	10	12	14	16	18	20	22	24	26	28	30
	Square Feet of Direct Radiation Supplied Under Pressure Difference of 5 Pounds. Emissive Capacity of Radiation = 160 B. T. U. per Hour										
$\frac{1}{4}$	200	230	260	290	320	350	380	410	440	470	500
$\frac{3}{8}$	400	460	520	580	640	700	760	820	880	940	1,000
$\frac{1}{2}$	600	690	780	870	960	1,050	1,140	1,230	1,320	1,410	1,500
$\frac{5}{8}$	840	960	1,090	1,210	1,340	1,470	1,590	1,720	1,840	1,970	2,100
$\frac{3}{4}$	1,090	1,250	1,410	1,580	1,740	1,910	2,070	2,230	2,400	2,560	2,730
$\frac{7}{8}$	1,360	1,560	1,770	1,970	2,180	2,380	2,590	2,790	3,000	3,200	3,410
1	1,630	1,880	2,120	2,370	2,620	2,860	3,110	3,350	3,600	3,850	4,090

TABLE VIII

FACTORS FOR CHOKER CAPACITY

Pressure Difference Pounds per Square Inch	Factor	Pressure Difference Pounds per Square Inch	Factor
1	.48	8	1.22
2	.64	9	1.29
3	.77	10	1.36
4	.90	15	1.55
6	1.10	20	1.74
7	1.16	25	1.92

62. With the use of a forced circulation of hot water no attention need be paid to the pitch of the flow and return pipes, which may be run side by side or one above the other,

as may be most convenient. The piping may be run over doorways or other obstructions without interfering with the circulation.

63. Various methods for preventing loss of heat from the street mains of hot-water heating systems have been adopted with more or less satisfactory results. In practice it has been found that, besides the street-main protection, it is desirable also to cover the cellar mains and risers. Excessive loss of heat from cellar mains may be prevented at comparatively small expense by cutting up 100-pound rolls of asbestos paper, $\frac{1}{16}$ inch in thickness, into sections 6 inches wide, and then wind the strip several times around the pipe, first in one direction and then in the reverse. Further economy is secured by covering the risers as well, so that in very mild weather the heat that would otherwise be given off by them need not be dissipated by the opening of doors and windows when the temperature in the room becomes too high, even with all the radiators shut off.

64. Temperature regulation in district hot-water heating plants is effected in two ways: By hand or thermostatic regulation in each building served, the temperature of the water delivered being constant; or, by station regulation through variation of the speed of the pump or of the temperature of the water forced through the mains. The speed of the pump may be controlled automatically by thermostatic apparatus, or by an attendant, to suit the demand for heat, as indicated by the temperature of the return water. When the pump is operated at a fixed speed, the temperature of the water is varied at the station to suit the requirements of the weather. Then, by adjusting the radiator valves, the proper amount of water is constantly circulated through the radiation in each building, and from the beginning to the end of the heating season the customer need pay no attention whatever to the regulation of the heat supplied.

DISTRIBUTING SYSTEMS

CLASSIFICATION

65. There are three systems of hot-water distribution; viz., the *single-main closed-circuit system;* the *double-main open-circuit system;* and the *double-main closed-circuit,* or *balanced-column, system.* In single-main systems, the street main is of the same size throughout its entire circuit; whereas, with the double-main system, the supply and return pipes may be reduced in size, according as the amount of radiating surface to be supplied diminishes, as the distance from the station increases. For lateral branches, the double-main system permits the use of smaller piping than can be used in the loop or shunt necessary with the single-main system. This advantage, however, may in some cases be offset by the fact that the cost of installing a single-main system is less than that for a double-main system.

SINGLE-MAIN DISTRIBUTION

66. With the **single-main system,** as indicated in Fig. 16, the water that passes through the piping system of one building must also pass through the piping and radiators

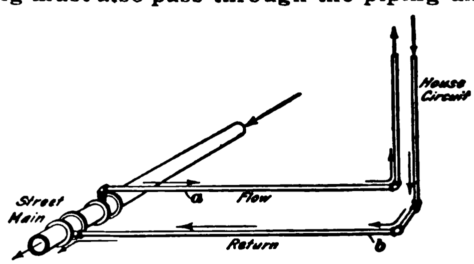


FIG. 16

of other buildings before it returns to the heater at the central station. As shown, the house-service flow connection *a* is taken from the top of the main, the return connection *b* being made to the side of the same main, a short distance in

advance of the supply connection. The branches on the underground main may be fitted with internal partitions to divert part of the current into the branch pipes; or the branches may be made with 45° fittings.

67. With the **double-main system,** as indicated by Fig. 17, the water passed through one building does not enter another before its return to the station. The water flows from the street supply, or flow, main through the pipes and radiators in the building and thence into the

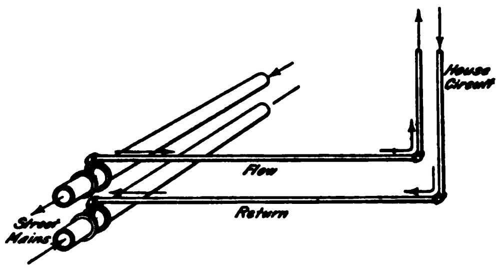


FIG. 17

street return main, each building thus having a distinctly separate supply and return. As the pressure in the flow main is higher than the pressure in the return main, a strong and positive circulation of water is obtained through the heating systems in the buildings.

68. With the **Evans-Almirall system,** as indicated by Fig. 18, which is a map of the system installed in the central part of a town, the distributing main forms a continuous circuit, or closed loop, having what are commonly termed shunts A, A extending off from the main line. The hot water is forcibly circulated by means of a centrifugal pump inserted directly in, and hence forming a part of, the circuit, which is completely closed.

The pipe forming the main circuit of the system shown in Fig. 18 is 5 inches in diameter, with 3-inch shunts, there being about 5,500 feet of main. One of the shunts is longer than the others, serving a greater amount of radiating surface; a valve a is placed in the 4-inch by-pass for this shunt,

to cause a proper amount of water to flow through the shunt by offering resistance in the by-pass. The mains are enclosed in wooden conduits and are laid in trenches about 3 feet deep. Both the supply and the return to the buildings

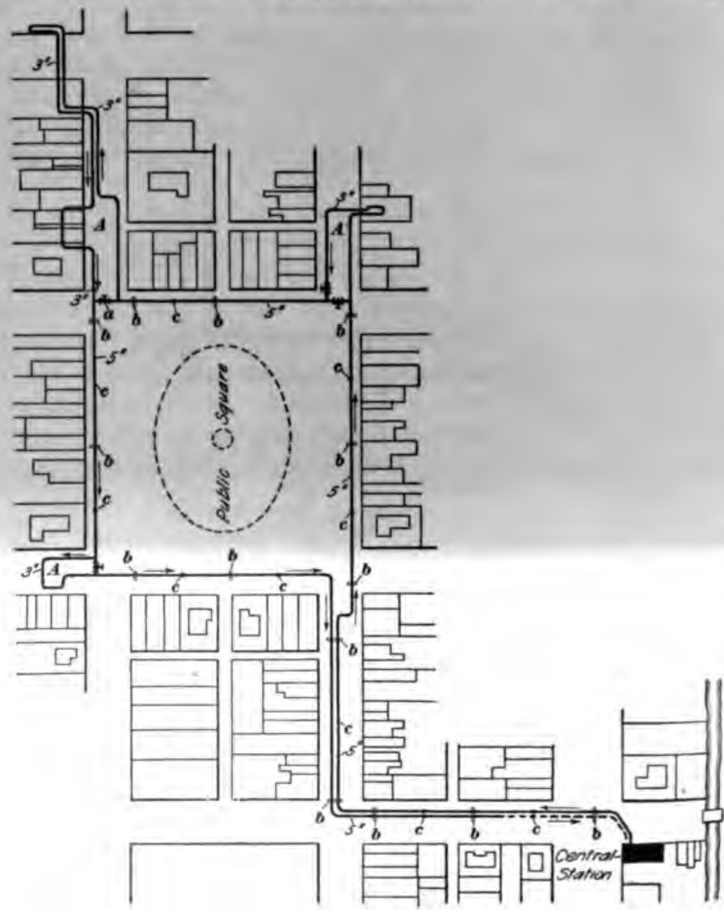


FIG. 18

are connected to the main with a valve in each pipe, so that each house is heated on a shunt, and the circulation is obtained by the difference in the frictional resistance in the branch and the main pipes. The mains are anchored at

each of the points *b* by a wrought-iron strap passing over the pipe, which it holds down on a cast-iron saddle, the ends of the iron strap projecting through a channel bar and being fitted with nuts. The anchor is enclosed in a double box, about a foot square, and the channel bar underneath extends about 18 inches each side of it, embedded in the trench filling. Slip expansion joints are located at *c* about midway between anchors.

69. A conventional illustration showing the arrangement of apparatus at the station is presented in Fig. 19. Exhaust steam from the engines first passes through an open feedwater heater and grease extractor *a* wherein the feedwater for the boilers is heated, and the cylinder oil is removed from the exhaust steam, which then passes through the closed exhaust heater *b*, where it gives up its heat to the circulating water for the heating system, the surplus exhaust steam, if

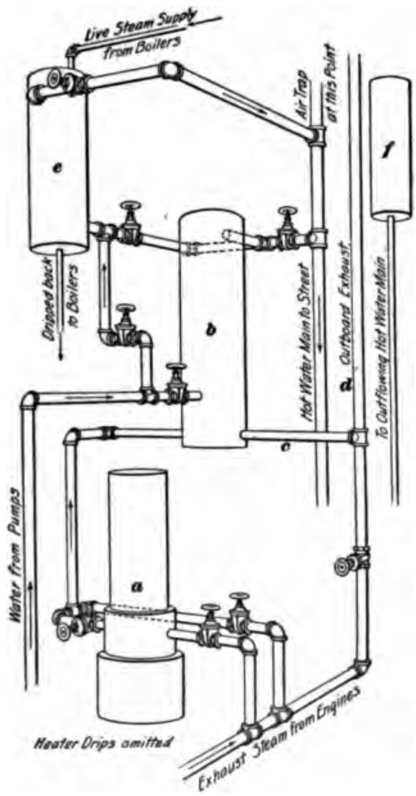


FIG. 19

any, escaping to the atmosphere through the connection *c* and exhaust escape pipe *d*. The exhaust heater *b* is elevated above the water-line in the open feedwater heater, so that the condensation from the exhaust steam will flow to the feedwater heater by gravity, to be pumped to boilers as feedwater. The exhaust heater *b* is usually open to the

atmosphere, so as to obviate back pressure on the engines. Elevated some distance above the boilers is a live-steam water heater *e* similar to the exhaust heater, but smaller. When live steam is required for heating it is taken from the main steam pipe directly to this heater, the steam passing through tubes surrounded by the circulating water of the system. The condensation from the live steam returns to the boilers by gravity at a temperature corresponding to the pressure. By-pass connections are provided, as shown, for cutting out of service any or all of the heaters, the exhaust steam then passing directly to the atmosphere through the exhaust pipe *d*. From the heater *b*, the hot water is pumped through the distributing main by a centrifugal circulating pump that maintains a difference in pressure of 20 pounds or more per square inch between the supply and return ends of the main. The piping system being closed, there is no unbalanced head of water to pump against, the pump receiving the benefit of the pressure due to the height of the highest radiator on the suction side of the pipe. With open-circuit systems using a storage tank, which leaves an open place in the return circuit, the balancing effect of the pressure that would otherwise exist on the return line is lost. The open-circuit systems require the use of a steam-driven duplex pump, using, say, 150 pounds of steam per horsepower-hour, while centrifugal pumps may be driven by a belt from an engine at an expenditure of about 28 pounds of steam per horsepower-hour. The closed expansion tank *f* may be located at any convenient point in the station.

70. With the single-main system of hot-water distribution, the service connection to each building, usually $1\frac{1}{2}$ inches for 1,200 square feet of radiation or less, is taken from the top of the main as shown in Fig. 16, but the return from the building is brought back into the side of the same main at a point beyond the supply connection, the piping in each building forming what is commonly called a shunt, through which only a comparatively small part of the current of water is diverted from the main circuit.

71. The supply of heat sent out from the station is regulated by varying the speed of the pump and, consequently, the amount of water circulated in a given time. Posted near the thermometer in the main supply pipe, in some hot-water heating plants, is a carefully tabulated schedule by which the engineer can tell at a glance how hot the water must be to warm the buildings to 70° at any given outside temperature, so that customers need not touch the radiator valves during an entire heating season. The fact that the temperature of the heating surface in the entire system may thus be controlled is of particular advantage in moderate weather.

DOUBLE-MAIN DISTRIBUTION

72. Yaryan System.—A conventional illustration of the arrangement of the apparatus of the **Yaryan system** is presented in Fig. 20. Exhaust steam from the engine passes through the pipe *a* into a closed heater *b* wherein it is condensed, the water of condensation passing through the drip pipe *c* to a receiving tank, from which the boiler feed-pumps pump it back into the boilers. The water to be heated is pumped from the expansion tank *d* through the heater *b* by the circulating pump *e*, the water being forced around the copper tubes of the heater and then into the outgoing supply main *f* for distribution. After passing through the pipe and radiators of the buildings to be warmed, the water returns to the expansion tank *d* through the return main *g*, again to be heated and pumped around the circuit. The return main is sometimes attached directly to the suction pipe of the pump, the expansion tank then being elevated above the highest radiator and connected to the return by a small pipe. When the available supply of exhaust steam is inadequate, the deficiency may be made up by using live steam from the boilers or by passing the water through an ordinary hot-water heating boiler forming a part of the circuit. When more exhaust is being produced than is required to heat the water, the excess is delivered to a water-storage tank to be used later when the electrical output is small.

The external circulating system consists of two wrought-iron pipes, laid side by side in the ground and carefully protected by insulation. One pipe serves for the outflow of hot water impelled by the pumps, and the other for the return water from the radiators in the various houses heated, which water goes back to the suction end of the pumps, to

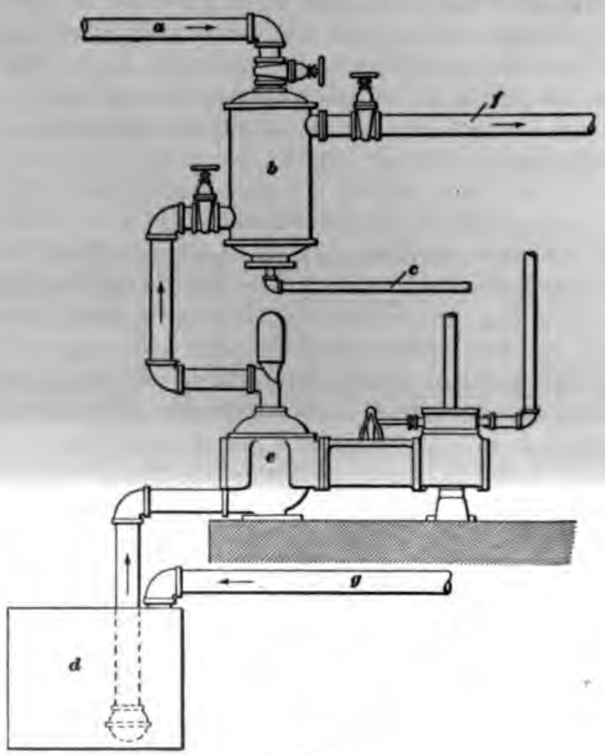


FIG. 20

be forced again through the heaters, where the loss in temperature is restored.

73. Expansion of the underground mains is taken care of by the use of an ordinary **U**, made as shown in Fig. 21, where the run is straight, and by means of 90° bends at corners. The **U**'s are placed about 600 feet apart, and as the extreme

expansion is about $\frac{3}{4}$ inch in 100 feet, each **U** takes care of $4\frac{1}{2}$ inches of expansion. When the mains are laid, an extra stress is put on the **U**'s in a direction opposite to that in which they will work when compensating for expansion. The service pipes to the various houses are 1-inch pipe, and

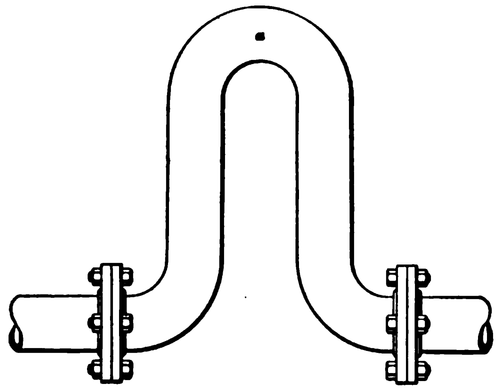


FIG. 21

the return line is throttled with a choker or perforated disk inside the building, the size of opening depending on the quantity of radiation, but averaging $\frac{5}{8}$ inch. To prevent serious loss of heat by conduction to the wet ground, usually found at greater depth, the mains are laid in a trench only 30 inches deep.

74. The insulation for the underground pipe lines is shown in Fig. 22. The top, bottom, and sides are made in separate sections by using for the top and bottom three 1-inch boards, separated with $\frac{1}{2}$-inch strips to form air spaces, with $1'' \times 4''$ boards on the sides to prevent the entrance of earth. The outside boards are creosoted, but the heat in the mains keeps all other boards dry.

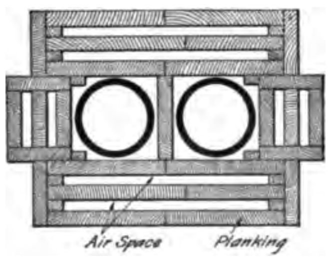


FIG. 22

75. The method of piping an ordinary small residence for use with the Yaryan system is shown in Fig. 23. Hot

water from the street main enters the house through a 1-inch service pipe *a*, the radiator connections being taken off in series, as indicated. Between the supply and return connections to each radiator, the main *b* is reduced in size to create sufficient resistance to direct the course of the water up or down as the case may be, and at the same time provide for

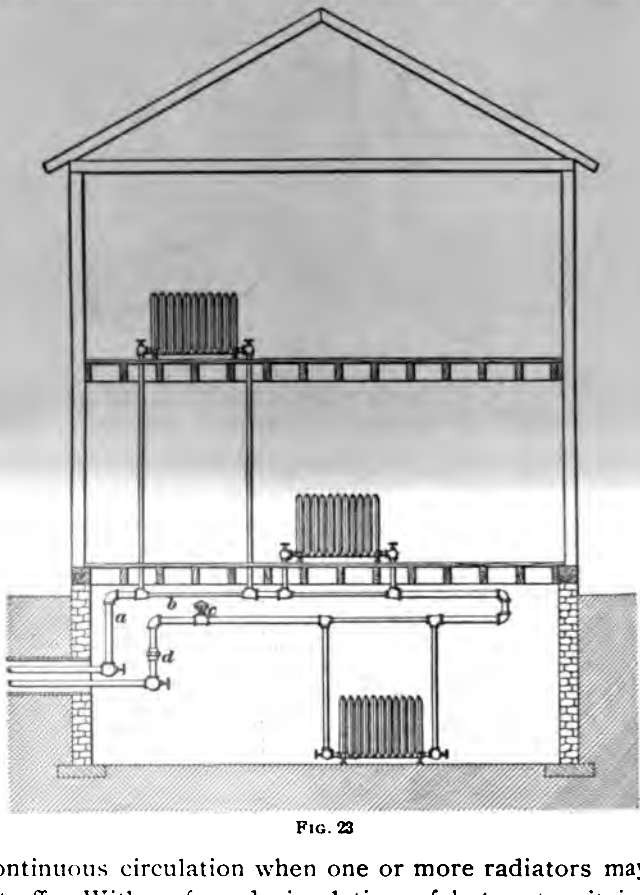


FIG. 23

a continuous circulation when one or more radiators may be shut-off. With a forced circulation of hot water, it is not necessary to consider the position of the radiator in relation to the supply main, nor has the pitch of the piping any appreciable effect on the direction or force of the circulation.

The flow of water is regulated by means of a thermostatic valve *c*, and a choker *d* in the return main. The amount of radiation installed should be somewhat greater than for a gravity hot-water heating system, because it has been found more economical to supply water at a comparatively low temperature than to use less radiation with a higher temperature.

76. Houses should be equipped with sufficient radiation to heat them to a temperature of 70° F. with an outside temperature of 30° above zero, the entering water being at 160°. By raising or lowering the temperature of the water 1° for each degree of variation in the outside temperature, an approximately constant temperature may be maintained in the houses in all kinds of weather. A pressure of about 30 pounds is usually maintained on the feed-line during cold weather, and about 40 pounds during moderate weather.

The loss of heat from the underground hot-water piping varies from 15 to 35 per cent. The drop in temperature in the supply main is approximately 1° for each 400 feet of length in the coldest weather, the loss depending on the character of the insulation.

The temperature of the hot water may be varied from 120° in mild weather to 210° in extremely cold weather.

77. Schott System.—The general arrangement of **Schott's balanced-column system,** having a closed circuit and double-main distribution, is indicated in a conventional way by Fig. 24. Exhaust steam from the engines, etc. passes through an oil separator *a*. A portion of the steam flows through the branch *b* to the open feedwater heater *c*, the balance flowing to the condenser *d*, where all of the remaining steam is condensed. This condenser is made up of 500 or 600 copper tubes having a diameter of from $\frac{1}{2}$ to $\frac{3}{4}$ inch. The shell of the condenser is made in two parts that are bolted together in such a manner as to form a flexible joint to accommodate expansion of the tubes, to prevent trouble from leakage. By either of the two duplex pumps *e, e* the circulating water is pumped through the

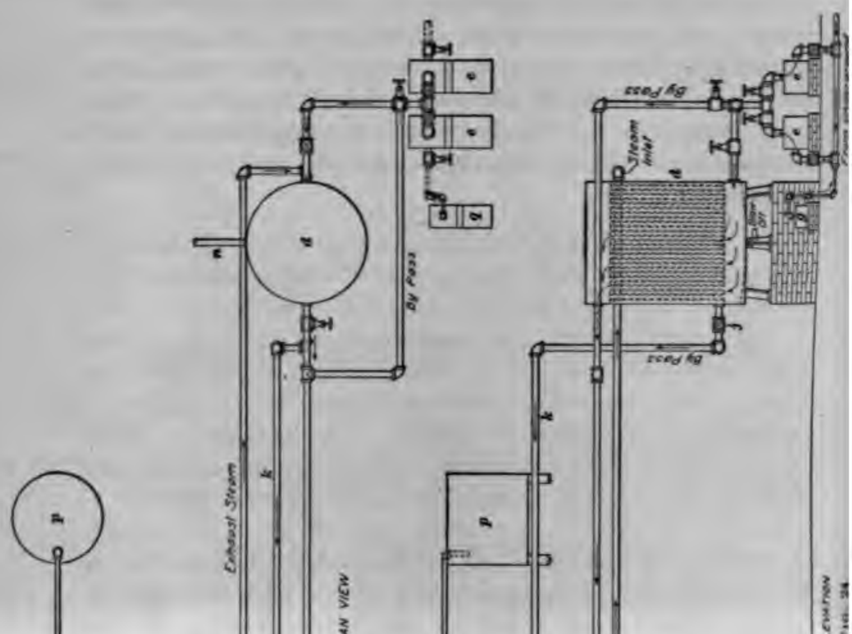

Exhaust Steam
PLAN VIEW
By Pass
Steam Inlet
By Pass
By Pass
Exhaust Steam
ELEVATION

Fig. 24

condenser tubes to the distributing mains, which are capped at the end of the circuit, so as to force all the water through the houses. In case the supply of exhaust steam is insufficient to heat the water to the required temperature, the water is by-passed through an auxiliary boiler *f* by opening valves *g* and *h* and closing valve *i*. The auxiliary heating boiler may be one of a battery of boilers, but being used as a hot-water heater, it is tapped the same size as the heating main at top and bottom. The water is pumped in at the top and goes out at the bottom into the distributing mains. In mild weather, when there is a surplus of steam, the latter may be passed through the condenser and then, by opening the valve *j*, through the piping *k* to the vapor pipe *l* above the back-pressure valve *m*, directly over the open feedwater heater. The water of condensation in the condenser is drained to the feedwater heater, or, when this is not possible, is discharged to the sewer through the pipe *n*.

Excessive pressure on the hot-water distributing pipes is obviated by a relief valve *o* of special construction, and the water discharged therethrough is allowed to run into the overflow tank *p*.

78. The term *balanced column* is applied to this system because of the fact that a small pump *q*, set close to the duplex pumps, is employed to maintain automatically any desired pressure up to, say, 40 pounds. The pump *q* takes its supply of water from the overflow tank *p*, feedwater heater *c*, or directly from the city water mains, and discharges into the suction of the duplex pumps, thus making up the leakage that occurs throughout the system and balancing the pressure on both sides of the pump. The pressure carried at the station depends on the distance the water is carried, height of buildings to be heated, rapidity of circulation desired, etc. It is not considered good practice to attempt to heat buildings more than three stories in height, nor is it desirable to carry over 40 pounds pressure in cast-iron radiators, which are commonly designed for about 40 pounds per square inch.

79. The flow and return pipes in the street are frequently placed side by side in an insulating box filled with soft-wood shavings. The box is made of 2-inch hemlock with a double bottom, solid sides, and a top with an air space, and at the service connections is usually made wide enough to admit of free lateral travel of service lines of not less than 3 inches. After the top of the box is laid on, the whole is covered with one thickness of heavy tarred or asphalted felt. Underdrains must also be provided where there is danger of water filling the box.

TABLE IX

SIZES OF SERVICE PIPES

Direct Radiation Square Feet	Length of Service Pipe. Feet		
	100	200	300
	Diameter of Service Pipe. Inches.		
500	1	$1\frac{1}{4}$	$1\frac{1}{4}$
750	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$
1,000	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$
1,500	$1\frac{1}{2}$	$1\frac{1}{2}$	2
2,000	$1\frac{1}{2}$	2	2
2,500	2	2	$2\frac{1}{2}$
3,000	2	$2\frac{1}{2}$	$2\frac{1}{2}$

As a rule, the street-main tappings for house-service connections are 1 inch, no matter how much radiation is to be supplied, but after leaving the 1-inch valve, placed to control the supply to the house, the size of the pipe is increased. House-service connections are taken from the top of the street-supply main. They are usually made with a swivel connection at the valve on the street main, running to and through the house foundation without anchors.

Ordinarily the house-service pipe is increased to $1\frac{1}{4}$ inches, and is dropped to the bottom of the street main and then run horizontally for about 4 feet, to allow for expansion, and then direct to the cellar, where the connections are made.

80. Table IX gives the sizes of service pipe required for various amounts of radiation.

81. With the Schott system of heating from a central station, as shown in Fig. 25 by a line diagram, it is customary to subdivide the main feed-line *a* in the cellar into loops or belts *b* by **OS** fittings or twin **L**'s, no belt carrying more than 250 square feet of radiation. All changes in direction of

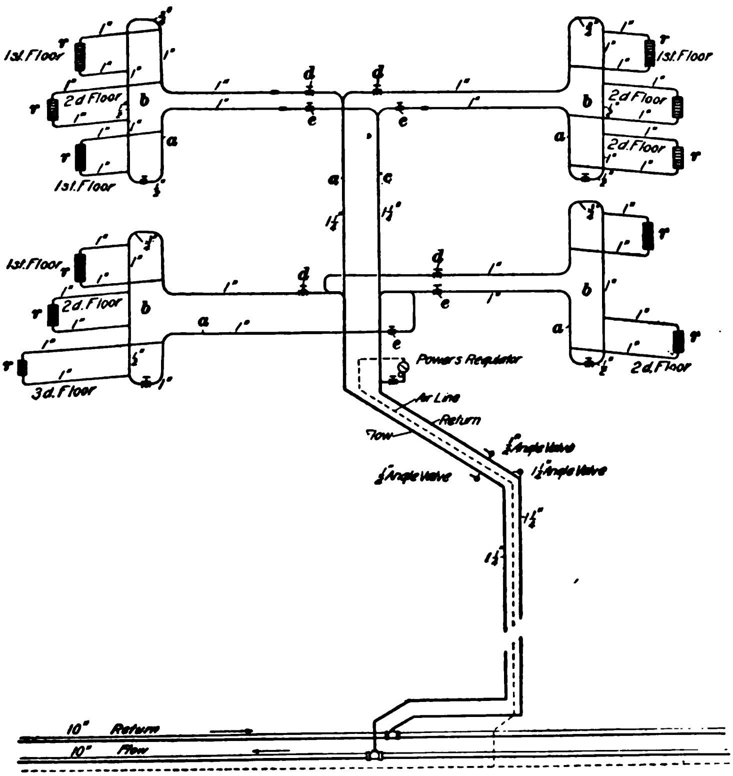


FIG. 25

runs of belts are made by bending the pipe, care being exercised not to flatten the pipe in bending it. Each belt is provided with a gate valve *d* at the point where it leaves the main feed, and another gate valve *e* where it reenters the return *c*, a plugged drip **T** is inserted at the lowest point of

each belt, so that when the gate valves *d, e* are closed the water may be drawn out of the piping and the radiators attached to that belt without affecting the operation of the balance of the heating system, thus facilitating repair work whenever necessary. The main feed-lines in the building are usually 1 inch for one or two belts; $1\frac{1}{4}$ inches for three or four belts; $1\frac{1}{2}$ inches for five to eight belts; 2 inches for nine to sixteen belts; $2\frac{1}{2}$ inches for seventeen or more belts, and when more than 100 feet long one size larger pipe than given is installed.

For heating ordinary residences, as indicated by Fig. 25,

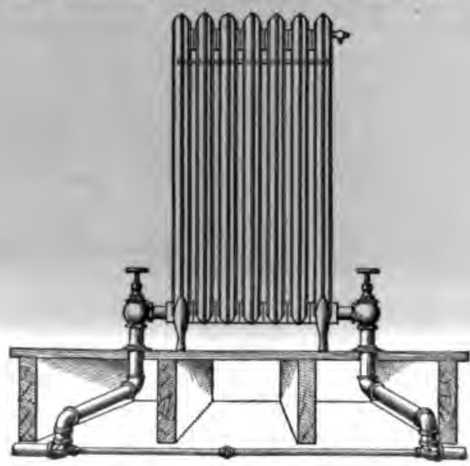


FIG. 26

each radiator *r* has a separate 1-inch supply from, and a return to, the belt, both supply and return connections being taken from the top of the belt piping, and the branch to each radiator has a horizontal run of not less than 18 inches, as indicated by Fig. 26. Each radiator is provided with a positive air valve, and a 1-inch radiator valve on the return as well as on the supply connection. Inserted in the belt mains between the supply and return connections to each radiator, as shown in Figs. 25 and 26, are pipes of smaller diameter, and of about the same length as the radiator. These pipes are commonly called *chokers*, the same term also

being applied to the perforated disk inserted in the return line of other systems of hot-water heating by forced circulation. The choker pipes are inserted for the purpose of controlling the circulation of the water, and, as indicated by Fig. 25, they are of different sizes, depending on the number

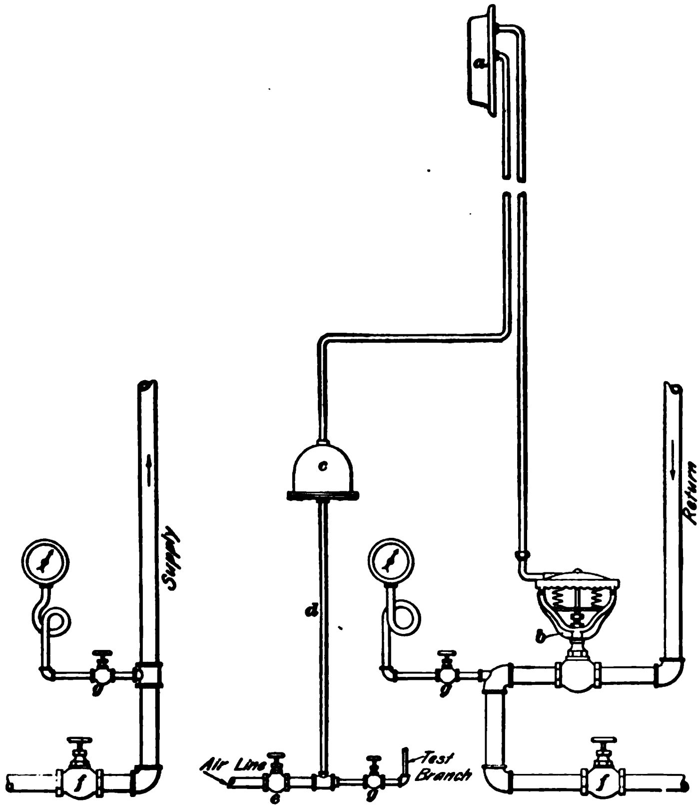


FIG. 27

and location of the radiators supplied and on other local conditions peculiar to each installation. It will be noticed that the first choker applied to the flow main of each belt is $\frac{3}{4}$-inch pipe, while $\frac{1}{2}$-inch choker pipes are employed at the other branch connections.

82. As indicated by Fig. 27, the apparatus by means of which the temperature in each house is automatically controlled comprises a thermostat *a* and a diaphragm valve *b*, together with an air filter *c* for removing particles of dust, scale, or other dirt that might clog the valves of the thermostat. For operating the valve *b*, a supply of compressed air from the central station is obtained through a $\frac{1}{4}$-inch service connection *d* taken off a $\frac{3}{4}$-inch air service pipe running into the cellar from the street. The flow of the compressed air into the diaphragm chamber of the valve *b* is controlled by the operation of the thermostat *a*. The latter is adjusted to maintain any desired temperature from 60° to 80° by actuating the valve *b* so as to control the flow of water through the heating system. The thermostat is placed on the wall in a central part of the house, at a distance of about $5\frac{1}{2}$ feet from the floor. It is connected to the valve *b* and filter *c* by means of $\frac{1}{4}$-inch armored lead tubing wound with galvanized steel wire. The tubing may be connected by brass couplings with soldered joints. The regulating valve *b* is placed in the return pipe as shown. The supply of compressed air from the station is furnished by a compressor equipped with an automatic governor for maintaining at all times a pressure of 15 pounds per square inch in the street air main. A shut-off cock *e* is placed in the house-service air pipe to permit cleaning the cotton-filled filter *c* if necessary, but if care is exercised in laying the street air main the filter will remain in operative condition for years without cleaning. An air pressure of 10 pounds is sufficient to close entirely the diaphragm valve against the pressure of the coil springs that are provided to open the valve when the air pressure on the actuating diaphragm is released by the operation of the thermostat when the temperature falls below that at which the house is to be maintained. Actuated by the temperature to which it is exposed, the thermostat allows air to pass through it to the diaphragm chamber with sufficient pressure to close the valve tight. For example, with a rising temperature, the thermostat being set at 70° the valve *b* remains wide open until the temperature in the house reaches 68° or 69°, whereupon the

thermostat allows the compressed air to pass to the diaphragm chamber of the valve *b* and close it.

There is no escape of compressed air from the apparatus except when the temperature falls and the valve is opened by the springs as the air pressure is released. The street air main, and the house-service connections therefrom, should be of galvanized iron. A 1-inch main is sufficient to carry air a distance of 2 miles and supply air for operating 250 thermostatic regulating valves. The fuel saving effected by the use of automatic regulation in some cases amounts to approximately 40 per cent.

Just inside the building, valves *f* are placed on the hot-water supply and return pipes. On the house side of these valves, and also of the air cock *e*, test branches controlled by stop-valves *g* are provided. The size of each test branch on the water pipes is $\frac{1}{2}$ inch, and $\frac{1}{4}$ inch on the air supply pipe. The test branches are provided as a ready means of attaching pressure gauges for testing purposes.

A SERIES

OF

QUESTIONS AND EXAMPLES

RELATING TO THE SUBJECTS
TREATED OF IN THIS VOLUME.

It will be noticed that the Examination Questions that follow have been divided into sections, which have been given the same numbers as the Instruction Papers to which they refer. No attempt should be made to answer any of the questions or to solve any of the examples until that portion of the text having the same section number as the section in which the questions or examples occur has been carefully studied.

STEAM GENERATION

EXAMINATION QUESTIONS

(1) Briefly define radiation, conduction, and convection.

(2) On what does the rate of transmission of heat through the boiler heating surface depend?

(3) Briefly state how the circulation within a boiler may be aided.

(4) (*a*) How is the heating value of coal usually measured? (*b*) What are the principal constituents of coal?

(5) (*a*) State about how many British thermal units are given off in the complete combustion of 1 pound of anthracite coal. (*b*) In practice, about how many heat units per pound of coal are absorbed by the water in the boiler?

(6) On what does the rate of combustion of fuel depend?

(7) Suppose the amount of direct radiation in a building to be 6,500 square feet and the height of the chimney to be 30 feet, what should be the effective area of the chimney? The chimney is located inside the building, and is round.

Ans. 1.453 sq. ft.

(8) If a square chimney has an effective area of 4 square feet, what should be the actual inside length of the sides?

Ans. 28 in.

(9) The effective area of a round chimney being 3 square feet, what should be the actual inside diameter?

Ans. 27.5 in.

(10) What should be the height of a chimney to provide a satisfactory draft, the direct radiating surface being

15,000 square feet and the effective area of the chimney 5 square feet? Ans. 81 ft.

(11) The actual area of a chimney being 9 square feet, what is the effective area? Ans. 7.2 sq. ft.

(12) A chimney 100 feet high has an effective area of 4 square feet. For what size plant, expressed in engine horsepower, would the chimney be large enough? Ans. 133.2

(13) A sectional house-heating boiler of the vertical slab type has 14 sections, each 46 inches across the flue and 48 inches high above the grate, and 6 inches in depth. What is the approximate heating surface in square feet? Ans. 451 sq. ft.

(14) If a boiler contains 250 square feet of boiler heating surface, approximately how many square feet of direct radiation will manufacturers rate it as being able to supply? Ans. 2,500 sq. ft.

(15) A horizontal return-tubular boiler has a diameter of 50 inches, length of tubes 10 feet, internal diameter of tubes $2\frac{1}{2}$ inches, number of tubes 80. How many square feet of heating surface has the boiler? Ans. 623.5 sq. ft.

(16) A return-tubular boiler is to generate 1,000 pounds of steam per hour; burning coal at the rate of 12 pounds per square foot of grate surface per hour, what grate area will be required? Ans. 9.8 sq. ft.

(17) If a house-heating boiler is rated to supply 800 square feet of direct radiation under ordinary conditions, how many square feet of grate surface will be required? Ans. 8 sq. ft.

(18) How many British thermal units absorbed per hour constitute a boiler horsepower?

(19) If a boiler receives the feedwater at 50° and evaporates it into steam at 60 pounds gauge pressure, what is the standard horsepower of the boiler if 2,000 pounds of water is evaporated into dry steam per hour? The total heat

of a pound of steam at 60 pounds gauge pressure is 1,175.6 British thermal units? Ans. 69.46

(20) What heating surface should be given to a water-tube boiler that is to furnish 10,000 pounds of steam per hour, the height of the chimney being 120 feet and the actual area of the chimney 9 square feet? The ratio of heating surface to grate surface may be taken as 1 to 40.

Ans. 2,540 sq. ft.

(21) A boiler 50 inches in diameter is constructed of steel plate, having a tensile strength of 50,000 pounds per square inch, and $\frac{1}{2}$ inch thick. The seams are double-riveted, and have a lap joint. What may be the working pressure?

Ans. 140 lb. per sq. in.

(22) Is it advisable to place a stop-valve between a power boiler and its safety valve?

(23) What care should be given to the heating surfaces in order to secure the greatest efficiency and economy in the operation of a boiler?

(24) What is the difference between foaming and priming in boilers?

(25) Briefly state how scale can be prevented from forming in boilers.

PIPE-FITTING TOOLS

EXAMINATION QUESTIONS

(1) How are adjustable pipe tongs constructed?

(2) What type of pipe tongs is best adapted to screwing up pipe of large diameter?

(3) For what class of work are friction wrenches best adapted?

(4) Suppose that a steam pipe runs within 2 inches of the angle of a wall, and it becomes necessary to cut the pipe in order to effect repairs and without taking down the pipe; what kind of pipe cutter is best adapted for this?

(5) Briefly describe the process of cutting wrought-iron pipe by means of a hand pipe cutter.

(6) State how the burr that is formed in the end of pipe while being cut with a wheel cutter can be removed.

(7) What is the operation of cutting screw threads on the outside of pipes called?

(8) How are the dies adjusted in the Armstrong die stock to cut a standard size of thread?

(9) What are the advantages of a self-centering, adjustable, die stock?

(10) Suppose that it is necessary to cut a thread on a 2-inch pipe located close to a wall so that it cannot be removed; how can the thread be cut?

(11) On what does the tightness of a screw joint depend?

(12) What is the standard taper for the threaded part of pipe taps?

(13) State by what means the spindle of a breast drill is usually driven.

(14) In placing pipe in a frame building, how can it be determined where to cut the holes in the flooring or walls and avoid obstructions?

(15) How are floor chisels constructed, and for what purpose are they employed?

(16) What is the best material to use on the threads when making screw joints?

PIPE-FITTING PRACTICE

(PART 1)

EXAMINATION QUESTIONS

(1) If, in testing a piping system, a sand hole is found in one of the fittings, how can it be repaired permanently without removing the fitting?

(2) State how cement is applied to threaded pipe joints in order to prevent the cement from being forced inside the pipe.

(3) How are the measurements for iron pipework taken?

(4) What length of pipe will it require to make an offset of 5 feet, at an angle of 45°, allowing $1\frac{1}{4}$ inches at each end for the fittings? Ans. 6 ft. $10\frac{3}{8}$ in.

(5) Give three prime reasons why steam pipes should be bent to change their direction.

(6) Suppose you are called on to bend a 2-inch pipe to a radius of about 25 inches, how would you proceed in order not to flatten or kink the pipe? A plank is to be used for making the bend.

(7) How are brass and copper pipes prepared in order that they may be bent properly?

(8) In bending pipes hot without the aid of forms, when one part has become sufficiently bent, how would you prevent further bending of that part?

(9) State for what purpose a templet is used in bending pipe.

(10) Briefly describe how the pipe fitter should proceed to lay out working drawings for bent pipework, in order that the work may be accurately done in the shop.

(11) In running a tall riser, at about what point should it be anchored in order to reduce the expansion in relation to the anchor to a minimum?

(12) Name the principal pipes in a heating system, and state the function of each pipe.

(13) How should a globe valve be placed on a steam pipe so that the stem can be easily repacked?

(14) If a steam main 100 feet long is installed at a temperature of 40° F., how much will it expand if steam is admitted into the line at 220° F.? Ans. 1.48 in.

(15) How are risers usually connected to a steam main when they are put in place before the main is installed?

(16) Suppose that a new gasket is required in a 4-inch flange union. The old gasket has become hardened and adheres to the face of the union; how can it be removed in order to leave a smooth, clean surface on the face of the union? The pipe line cannot be removed in any direction.

(17) Should common threaded unions that require gaskets to make them tight be used in steam work? Give reason.

(18) Describe the use of a relay in steam pipework.

(19) It is not desirable to use expansion joints on a certain very tall riser. How can provision be made for the expansion?

(20) If necessary to make an offset at an angle of 90° in a riser of a one-pipe system, what precaution must be taken in order to obtain good drainage against the flow of steam?

PIPE-FITTING PRACTICE

(PART 2)

EXAMINATION QUESTIONS

(1) What is generally required of the pipe fitter in charge of a job?

(2) On arriving at the job, what is the first work to be done?

(3) A 4-inch steam main is reduced to 3 inches by the use of a common reducing coupling; how would you prevent water from accumulating at the point where the pipe is reduced?

(4) How should the branches be taken from a steam main in order that the steam to the radiators shall be as dry as possible?

(5) (*a*) How are dry returns run? (*b*) State where the returns from radiators are connected.

(6) In case the steam main is not located well above the the water-line, or in case the steam main is not sufficiently large, what precaution should be taken to prevent the water in the boiler backing up into the return when steam is first turned on?

(7) In vertical slab boilers, the water-line is often so close to the steam drum that water is carried into the drum with the steam; how can this water be removed from the steam drum?

(8) At what height should an automatic water feeder be placed on a boiler?

(9) When independent equalizing pipes are used in connecting up two or more boilers, what should be the sizes of the steam and water connections compared with the steam and return mains?

(10) In large heating plants, where power boilers are required, how is the water of condensation returned to the boilers?

(11) What is the object of using a pump governor in connection with a boiler feed-pump?

(12) Is it advisable to have the discharge pipe of an ordinary low-pressure steam trap run above or below the level of the trap? Give your reason.

(13) Is it advisable to use exhaust-steam feedwater heaters in connection with power boilers? Give reason.

(14) Why is an exhaust head placed on the exhaust pipe where it terminates above the roof?

(15) How can oil be removed from exhaust steam in order that the steam may be used for heating or other purposes?

(16) In large heating plants, where high-pressure steam is used for power and heating, by what means can low-pressure be carried on the heating system?

(17) How are automatic sprinklers set in operation during a fire?

(18) At what temperature should the solder used in closing automatic sprinklers melt?

(19) What is the difference between wet and dry systems of automatic sprinklers?

(20) What size pipe is required to supply with water a sprinkler system having 112 sprinklers?

(21) How should the piping of automatic water feeders for low-pressure steam boilers be arranged?

(22) What are the chief requirements to be met in connecting twin boilers to the same piping system?

(23) What general provision should be made in making connections to auxiliary apparatus of combined heating and power plants, so that the service will not be interrupted when the apparatus is closed for repairs?

STEAM-HEATING PIPE SYSTEMS

(PART 1)

EXAMINATION QUESTIONS

(1) In house-heating work, how should the steam main be graded in order to drain properly?

(2) Describe an overhead steam main and state the name of the pipe that feeds it from the boiler.

(3) Describe the difference between a dry and a wet return main.

(4) For every pound of steam condensed in a radiator, how many British thermal units must be transmitted from the surface of the radiator?

(5) In all heating systems, what causes the flow of steam to the different radiators?

(6) What are the principal obstructions to the free flow of steam to be found in a heating system?

(7) In planning a piping system, what must be considered and provided for as regards the condensation of the steam and the heating and cooling of the pipes?

(8) Describe how water hammer is caused in steam pipes.

(9) If a wet return main is $2\frac{1}{2}$ inches in diameter, what should be the size of a dry return main to do the same work?

(10) What size main is required in an ordinary residence to supply 600 square feet of direct radiation? Use empirical rule. Ans. $2\frac{1}{2}$ in.

(11) What size pipe is required to supply steam at a pressure of 5 pounds in a two-pipe system to 450 square feet of indirect radiation, the length of pipe being 100 feet?

Ans. $2\frac{1}{2}$ in.

(12) What size main is required to supply 20,000 square feet of direct radiation 100 feet long on a one-pipe system?

Ans. 10 in.

(13) What should be the size of a steam main, 100 feet long, that is required to supply 300 square feet of direct radiation on a one-pipe system, the available drop in pressure being equal to 6 inches of water column? Ans. 2 in.

(14) A one-pipe riser supplies 500 square feet of direct radiation; what should be the size of the drip pipe that connects its base with the return? Ans. $1\frac{1}{2}$ in.

(15) If a 3-inch steam main 100 feet long will supply 900 square feet of direct radiation, on a two-pipe system, how many square feet of radiation will it supply if the main is 400 feet long?

STEAM-HEATING PIPE SYSTEMS

(PART 2)

EXAMINATION QUESTIONS

(1) Briefly describe the general direction of the flow of steam and water of condensation throughout a one-pipe system having a main run around the cellar in the form of a loop.

(2) Briefly describe how the main is run in a circulating main system for low-pressure heating.

(3) If, while installing a steam main, it is found that the lowest point in the main is only 18 inches above the water-line in the boiler, how would you prevent the water in the boiler being forced back through the return and flooding the main when steam is first turned on?

(4) What advantage is derived from installing the dripped main system of piping having a drip at the base of each riser, or riser connection to main?

(5) When return pipes are run under a cellar bottom below the level of the boiler, what provision should be made so that they will be easy of access and will be drained?

(6) What is the object of using sealed drips in combination with a dry-return main?

(7) Describe the one-pipe down-feed, or Mills, system of steam distribution, and state what advantage it possesses over the ordinary up-feed type of one-pipe system.

(8) What is the chief objection to the two-pipe connection to radiators in low-pressure heating for ordinary dwellings?

(9) What is the principal distinguishing feature of a two-pipe heating system?

(10) Describe, briefly, the common-feed and separate-return system of piping.

(11) What is the distinguishing difference between the wet- and the dry-return system of piping?

(12) If a return riser is required to be connected to a dry-return main, explain how the connection can be made so that steam will not pass up the return riser.

(13) How should relief or drip pipes from risers be connected to a main return located directly beneath the risers in order to allow for expansion?

(14) Distinguish between the one-pipe and the two-pipe down-feed systems.

(15) Describe, briefly, the method of warming buildings by indirect radiation.

(16) Briefly describe the semidirect system of heating.

(17) Which is the better practice, to permit the automatic air valves to discharge into the rooms or to connect them to a separate system of piping that will discharge the air to a flue or the outer atmosphere? Give reasons.

EXHAUST AND VACUUM SYSTEMS

EXAMINATION QUESTIONS

(1) Which is the more economical, to carry a back pressure on the engine in order to utilize the exhaust steam for heating purposes, or to heat with live steam direct from the boiler, allowing the engine to exhaust into the atmosphere?

(2) Should the exhaust steam from an engine be discharged directly into the heating system? Give reasons.

(3) In installing an exhaust steam-heating system, what provision should be made for supplying the heating system with steam when the engine is shut down?

(4) In the event of the return main being connected to the bottom of the receiver of a pump governor, what steam-pipe connection is necessary to insure a proper action of the governor?

(5) Briefly describe the combination high-and-low pressure system in which atmospheric pressure may be maintained in the return tank.

(6) How does the vacuum system of heating differ from the ordinary low-pressure heating system?

(7) Name one of the chief advantages of the vacuum system of heating using exhaust steam.

(8) Before inserting the interior mechanism in the motor valve used in the Webster vacuum system, what precautions must be taken regarding the cleaning of the system?

(9) Briefly describe the essential features of the Paul system of heating.

(10) In the Morgan system of heating, how large a pipe is required for the main air line if the system contains thirty radiators of ordinary size? Ans. $\frac{3}{4}$ in.

(11) Briefly describe the mercury seal used in the Trane vacuum system of heating, and state how it operates.

(12) In installing a vacuum system of heating, what precautions must be taken in order that the vacuum may not be lost too rapidly?

(13) Define the term vacuum system of heating.

(14) What is the difference between a vacuum system and a so-called vapor system of heating?

(15) How are the supply and return connections made to the radiators in the Broomell system of heating?

(16) In a low-pressure one-pipe system of heating, what advantage is derived from the application of the Allen automatic air valve?

(17) The available amount of exhaust steam from an engine is 2,000 pounds per hour; how much radiation can be supplied by the exhaust? Ans. 8,000 sq. ft.

HOT-WATER HEATING SYSTEMS

EXAMINATION QUESTIONS

(1) On what does the velocity of circulation depend?

(2) A hot-water heating system contains 200 cubic feet of water at 55° F.; how much will the water expand if the temperature of the water is raised to 200° F.?

Ans. 7.702 cu. ft.

(3) If a vertical pipe uniform in diameter is filled with water to a height of 40 feet, how many inches will the water rise on being heated from 50° F. to 190° F.? Ans. 16.728 in.

(4) What is understood by the term motive force, as applied to a hot-water heating system?

(5) What is the total motive force per square inch in a hot-water heating system, the average temperature in the ascending column being 200° F.; and that in the descending column 160° F., the operative height of the descending column of water being 30 feet? Ans. .189 lb. per sq. in.

(6) In an ordinary hot-water system of heating how can air be prevented from accumulating in the system?

(7) What is the object in using an expansion tank in connection with a hot-water heating system?

(8) What is the minimum size of an open expansion tank required to provide for the expansion in a heating system containing 500 gallons of water? Ans. 22.2 gal.

(9) Briefly describe how the water in an open-tank system can be automatically controlled.

(10) Describe briefly the difference between the open and closed system of hot-water heating.

(11) Explain how it is that air gathers at the highest points of a hot-water system of heating.

(12) In installing a system of hot-water heating, how should the flow and return main be run so that the air will be readily liberated?

(13) To what extent will an air lock affect the circulation in a hot-water apparatus?

(14) How should branches be taken off the hot-water main to supply indirect radiation that is located below the main? Give reason.

(15) Describe briefly the simple-circuit system of hot-water heating.

(16) Briefly describe the compound-circuit system of hot-water heating.

(17) What is the theoretical velocity with which water will flow through a circuit the vertical height of which is 30 feet, the temperature of the flow main being 180° F. and that of the return 160° F.? Ans. 3.828 ft. per sec.

(18) In installing a hot-water system, what precautions must the fitter observe with the pipes in order that the friction in the piping system may be reduced to a minimum?

(19) Describe how the flow and return branches to the radiators are connected to the main in the one-pipe hot-water system.

(20) State one of the principal advantages derived by installing a drop system of hot-water distribution.

(21) What is the principal object to be sought in designing a hot-water heating system?

(22) It is found that a 2-inch pipe is the proper size to supply a radiator on the first floor; what size of pipe will be required to supply the same radiator on the fourth floor? Ans. $1\frac{1}{2}$ in.

(23) With a two-pipe system of hot-water heating, how many square feet of direct radiation will be required on the first floor for a room containing 325 square feet of exposed wall surface, and 80 square feet of glass surface?

Ans. 101.6 sq. ft.

(24) What grate surface will be required in a boiler that is to supply 1,500 square feet of direct radiating surface, including piping, at a temperature of 160° F., burning 5 pounds of coal per square foot of grate surface per hour?

Ans. 5.07 sq. ft.

(25) What size of main is required to supply 700 square feet of direct radiation, the circuit being 200 feet long, on a two-pipe system? Ans. 4 in.

(26) What size of main will be required to supply 900 square feet of indirect radiation on the one-pipe circuit system, the length of the circuit being 190 feet? Ans. 5 in.

(27) 150 square feet of radiation is located on the third floor of a residence; what size of riser is required?

Ans. $1\frac{1}{4}$ in.

(28) What size of pipe should be used to supply 125 square feet of indirect radiation? Ans. 2 in.

(29) How many square feet of hot-water radiation are required to heat an ordinary greenhouse to 60° F. when the outside temperature is zero? The greenhouse has 2,400 square feet of glass and 600 square feet of exposed wall surface. Ans. 784.6 sq. ft.

(30) A circuit composed of 2-inch pipe contains ten ordinary elbows and four T's, what length should be added to the circuit to represent the resistance of the fittings?

Ans. 163 ft. 4 in.

HOT-WATER HEATING APPARATUS

EXAMINATION QUESTIONS

(1) Are the fittings commonly employed for steam work suitable for hot-water heating apparatus? Give reason.

(2) What class of fittings is best adapted for joining cast-iron pipes for greenhouse heating? Give reason.

(3) What are the principal requirements of valves employed in hot-water heating and how do they differ from those used in steam heating?

(4) Is it considered good practice to use globe valves in a hot-water system? Give reason.

(5) What provision should be made in hot-water radiator valves to prevent the water in the radiator from freezing when the valve is closed?

(6) Describe briefly a butterfly valve and explain its use in hot-water heating.

(7) Describe the principal difference in operation between a draft regulator for steam and a draft regulator for hot water.

(8) How may a hot-water heating system be arranged so that the level of the water in the expansion tank can be determined from the floors below?

(9) What must be considered in connecting up an expansion tank, in regard to stop-valves and frost?

CENTRAL-STATION HEATING

EXAMINATION QUESTIONS

(1) What would be the probable loss in pressure in a properly designed piping system for district steam heating, the mains being about a mile long?

(2) In a general way, how is the underground piping for central-station steam-heating plants usually installed?

(3) Why is the water of condensation from the mains and radiation of an extensive district steam-heating system discharged to the sewer instead of being returned to the boilers in the central station?

(4) By what means are expansion and contraction taken care of in the improved Holly system of district steam heating?

(5) Why is the use of slip expansion joints less desirable than that of variators for taking care of expansion?

(6) What type of valve has been found to give satisfactory service on underground steam piping systems?

(7) How may the work of running underground pipes at various angles to one another be facilitated?

(8) How and where is anchorage provided for underground mains of the improved Holly system?

(9) Where are service connections made to the underground piping, and why?

(10) How is underground steam piping usually protected against undue loss of heat?

(11) How is a uniform pressure maintained in the piping of buildings heated from a central station?

(12) What is the chief purpose for which cooling coils are used in connection with central-station heating, and what other purpose do they serve?

(13) What size of cooling coil should be provided to cool the water of condensation from 900 square feet of direct radiation to a temperature of 80° before being discharged to the sewer? Ans. 126 sq. ft.

(14) By what means is the amount of steam used by each consumer most accurately determined?

(15) What is the most equitable basis for fixing the rates charged for central-station steam heating?

(16) What should be the diameter of a steam main for supplying steam from a central station to buildings containing an aggregate of 26,000 square feet of direct radiation, the main being 1,500 feet in length and the steam pressure 5 pounds? Ans. 13 in.

(17) In central-station hot-water heating, how is the water circulated?

(18) What is an open-circuit system of central-station hot-water heating?

(19) What are closed-circuit and balanced-column systems of central-station hot-water heating?

(20) What amount of hot-water radiation would be required to heat a room having 354 feet of exposed wall surface, 64 feet of glass surface, and 3,300 cubic feet of space? Ans. 132 sq. ft.

(21) What is a choker and for what purpose is it employed?

(22) How much direct radiation may be supplied with hot water from a central station through a ½-inch choker

with a pressure difference of 10 pounds and a temperature drop of 20° F.? Ans. 1,428 sq. ft.

(23) What are the principal methods of securing temperature regulation in buildings heated from a central-station hot-water heating plant?

(24) How many systems of piping are commonly employed in the distribution of hot water from a central station, and what are they?

A KEY

TO ALL THE

QUESTIONS AND EXAMPLES

CONTAINED IN THE

EXAMINATION QUESTIONS

INCLUDED IN THIS VOLUME.

The Keys that follow have been divided into sections corresponding to the Examination Questions to which they refer, and have been given corresponding section numbers. The answers and solutions have been numbered to correspond with the questions. When the answer to a question involves a repetition of statements given in the Instruction Paper, the reader has been referred to a numbered article, the reading of which will enable him to answer the question himself.

To be of the greatest benefit, the Keys should be used sparingly. They should be used much in the same manner as a pupil would go to a teacher for instruction with regard to answering some example he was unable to solve. If used in this manner, the Keys will be of great help and assistance to the student, and will be a source of encouragement to him in studying the various papers composing the Course.

STEAM GENERATION

(1) Radiation may be defined as the transfer of heat through space, conduction the transfer of heat through solids, and convection the transfer of heat through liquids or gases. See Art. **1.**

(2) It depends on the difference in temperature between the water and hot gases, the thickness of the metal, cleanness, and relative positions of the heating surfaces. See Art. **2.**

(3) By attaching circulating tubes, baffle plates, or return tubes to the boiler. See Art. **11.**

(4) (*a*) It is usually measured by the number of heat units given out by the combustion of 1 pound of coal. See Art. **31.**
(*b*) Carbon and hydrogen. See Art. **31.**

(5) (*a*) About 13,500 B. T. U. See Art. **31.**
(*b*) From 8,000 to 9,000 B. T. U. See Art. **32.**

(6) It depends on the intensity of the draft. See Art. **33.**

(7) By the rule given in Art. **36** for a round chimney exposed entirely to the weather, $A_e = \frac{.003 \times 6{,}500}{\sqrt{80}}$ $= 2.18$ sq. ft. By the statements made in Art. **36,** the effective area may be reduced $33\frac{1}{3}$ per cent. for an inside chimney, or $2.18 \times .3333 = .727$ sq. ft. Then, the required effective area $= 2.18 - .727 = 1.453$ sq. ft. Ans.

(8) By rule I, Art. **37,**

$$l = 12\sqrt{4} + 4 = 28 \text{ in. Ans.}$$

(9) By rule II, Art. **37,**

$$d = 13.54\sqrt{3} + 4 = 27.45, \text{ say } 27.5 \text{ in. Ans.}$$

(10) By the rule given in Art. **38**,

$$H = \left(\frac{.003 \times 15{,}000}{5}\right)^2 = 81 \text{ ft.} \quad \text{Ans.}$$

(11) By rule I, Art. **40**,

$$A_e = 9 - .6\sqrt{9} = 7.2 \text{ sq. ft.} \quad \text{Ans.}$$

(12) By rule II, Art. **40**,

$$P = 3.33\sqrt{100} \times 4 = 133.2. \quad \text{Ans.}$$

(13) Considering the combined front and rear sections as equivalent to 1 intermediate section, there are 13 sections. Applying the method given in Art. **48**,

$$\text{heating surface} = \frac{(46 + 6) \times 48 \times 2 \times 13}{144} = 451 \text{ sq. ft.,}$$

nearly. Ans.

(14) By the statement in Art. **48**, it would be rated at $250 \times 10 = 2{,}500$ sq. ft. of radiation. Ans.

(15) Circumference of shell, $50 \times 3.1416 = 157$ in.; length of shell, $10 \times 12 = 120$ in.; heating surfaces of shell, $157 \times 120 \times \frac{2}{3} = 12{,}560$ sq. in.; circumference of tubes, $2\frac{1}{2} \times 3.1416 = 7.854$ in.; heating surface of tubes, $80 \times 120 \times 7.854 = 75{,}398.4$ sq. in.; area of the two heads, $50^2 \times .7854 \times 2 \times \frac{2}{3} = 2{,}618$ sq. in.; area through tubes, $(2\frac{1}{2})^2 \times .7854 \times 80 = 392.7$ sq. in.

By the rule given in Art. **49**,

$$\text{heating surface} = \frac{12{,}560 + 75{,}398.4 + 2{,}618 - 2 \times 392.7}{144}$$

$$= 623.5 \text{ sq. ft.} \quad \text{Ans.}$$

(16) By Table V, Art. **53**, an evaporation of 8.5 lb. of water per pound of coal may be expected. Applying the rule given in Art. **53**,

$$G = \frac{1{,}000}{8.5 \times 12} = 9.8 \text{ sq. ft.} \quad \text{Ans.}$$

(17) By the statement made in Art. **54**, a factor of 100 may be chosen. Then,

$$\text{grate surface} = \frac{800}{100} = 8 \text{ sq. ft.} \quad \text{Ans.}$$

(18) 33,330 B. T. U. See Art. **56.**

(19) Applying the rule in Art. **56,**

$$P = \frac{(1{,}175.6 - 50 + 32) \times 2{,}000}{33{,}330} = 69.46. \quad \text{Ans.}$$

(20) The effective area $= 9 - .6\sqrt{9} = 7.2$ sq. ft., by rule I, Art. **40.** The horsepower of the chimney $= 3.33\sqrt{120} \times 7.2 = 262.64$, by rule II, Art. **40.** By Art. **60,** rate of combustion per square foot per hour $= \frac{262.64 \times .6}{9} = 17.5$ lb. By Table V, Art. **53,** the amount of evaporation per pound of coal is 9. Applying the rule in Art **60,**

$$S = \frac{10{,}000 \times 40}{17.5 \times 9} = 2{,}539.7, \text{ say } 2{,}540 \text{ sq. ft.} \quad \text{Ans.}$$

(21) The efficiency of a double-riveted seam, by Art. **64,** is .7. Applying the rule given in Art. **64,**

$$P_s = \frac{\frac{1}{2} \times 50{,}000 \times .7}{5 \times \frac{50}{2}} = 140 \text{ lb. per sq. in.} \quad \text{Ans.}$$

(22) No. See Art. **99.**

(23) The heating surfaces must be kept clean, both on the inside and outside. No dust, soot, scale, or mud should be permitted to remain. See Art. **84.**

(24) Foaming is the production of foam or unbroken bubbles of water in the boiler, and is due to impurities in the water; priming is the production of a spray of water in the steam space, and is due to violent ebullition. See Arts. **86** and **87.**

(25) It may be prevented by passing the feedwater through a purifier, where the water, by coming in contact with steam, has its temperature raised until the carbonates and sulphates are precipitated, or by introducing various chemicals into the boiler. See Arts. **90** and **91.**

PIPE-FITTING TOOLS

(1) One bar has a parrot nose that fits around the pipe; this bar is slotted to receive a pin capable of being shifted and serving as the fulcrum of the second bar. The pin is shifted by a screw for adjusting the tongs to different sizes of pipe. See Art. **3.**

(2) Chain tongs. See Art. **4.**

(3) They are especially adapted to screwing up nickel-plated or polished brass pipe. See Art. **7.**

(4) A three-wheel pipe cutter. See Art. **10.**

(5) The cutter is placed on the mark where the pipe is to be cut. The handle is then screwed down, which forces the cutting wheel into the pipe, and the cutter is revolved around the pipe. The handle is screwed in more at each revolution to force the cutter deeper into the pipe, oil being used to reduce the friction, and this is continued until the pipe is cut. See Art. **11.**

(6) A reamer is pressed into the end of the pipe and revolved, the sharp edges of the reamer cutting off the burr. See Art. **12.**

(7) Pipe threading. See Art. **18.**

(8) By adjusting the dies so that the marks on them will coincide with those on the stocks. See Art. **21.**

(9) The principal advantages are that the dies are self-centering and can be removed from the pipe without running the dies back on the threads. Large pipe can be threaded by taking two or more cuts. See Art. **23.**

(10) By using a ratchet stock. See Art. **24.**

(11) On the accuracy with which the thread is cut and the close contact with the thread in the fitting. See Art. **26.**

(12) A taper of 1 in 16, also expressed as $\frac{3}{4}$ inch per foot. See Art. **31.**

(13) It is operated by means of a crank geared to the drill spindle by bevel gears. See Art. **38.**

(14) By drilling small search holes with a search gimlet. See Art. **40.**

(15) They are made with a wide, thin blade and an iron handle, and are used for cutting the tongue of floor boards and raising them. See Art. **42.**

(16) Boiled linseed oil. The oil lubricates the threads and thus permits the pipe to be screwed easily into the fitting. See Art. **53.**

PIPE-FITTING PRACTICE

(PART 1)

(1) If the hole is small, it can be closed by peening the metal around the hole with a hammer; if the hole is large, it should be drilled out and tapped and a plug inserted. See Art. **1.**

(2) The first three or four threads of the fitting and the entire male thread are very thinly painted with the cement. See Art. **2.**

(3) They are taken from center to center of the different pipe lines, allowance being made for the fittings. See Art. **6.**

(4) $1.4142 \times 5 \times 12 - (1\frac{1}{4} + 1\frac{1}{4}) = 82.352$ in., or $\frac{82.352}{12}$ $= 6$ ft. $10\frac{3}{8}$ in., nearly. Ans. See Art. **7.**

(5) To reduce resistance to the flow of steam through the pipe, to avoid weakness due to fittings subject to stresses, and to have the pipe present a neat appearance. See Art. **9.**

(6) A hole is bored through a plank just large enough to receive the pipe. The pipe is then pressed downwards, bending it a little at a time at different points until the desired radius is obtained. See Art. **10.**

(7) In order that brass and copper pipes may be bent properly, it is necessary first to anneal them. This is accomplished by heating the places to be bent red-hot and then cooling them in water. See Art. **12.**

(8) When the correct curve is obtained in any part of the pipe this part can be chilled by pouring water on the properly formed part. The remaining parts can then be bent satisfactorily. See Art. **15.**

(9) It is used to determine when the proper curve or bend is obtained. See Art. **17.**

(10) The pipe fitter must determine the exact location of the several lines of pipe and then make a separate sketch of each bend and offset required, giving all dimensions and instructions to do the work accurately. See Arts. **18** and **19.**

(11) It should be anchored in the middle of its length. See Art. **22.**

(12) A steam main conveys the steam to the different parts of the heating system. A return main carries the water of condensation back to the boiler. A riser conveys the steam from the mains vertically to the radiators. Relief, drip, or bleeder pipes relieve the risers or low points in the steam pipes of condensation. See Art. **27.**

(13) It should be connected so as to close against the steam pressure. See Art. **30.**

(14) $100 \times 12 \times (220 - 40) \times .00000686 = 1.48$ in. Ans. See Art. **44.**

(15) They are connected with right-and-left fittings or flange unions. See Art. **32.**

(16) The gasket can be removed by using a hand saw. See Art. **34.**

(17) No. Because such unions are liable to leak. See Art. **37.**

(18) It is used in a long run of pipe where it is impracticable to grade the pipe uniformly throughout its entire length. The pipe can then be raised by a relay and more headroom thus obtained. See Art. **38.**

(19) The expansion may be provided for by inserting spring pieces, loops, or swivel connections in the riser. See Arts. **45** and **46.**

(20) The horizontal pipe must be inclined enough to be properly drained of all condensation. See Art. **49.**

PIPE-FITTING PRACTICE

(PART 2)

(1) To see that all work is done in accordance with plans and specifications; to keep account of all time and material, take measurements, to make sketches of special work to be gotten out at the shop, etc. See Arts. **1** to **7.**

(2) The bench is set up, and the tools and fittings arranged in a convenient place, near the bench. See Art. **8.**

(3) By connecting a drip pipe near the reducing coupling, allowing the water to drain into the return main. See Art. **12.**

(4) They should be taken from the top of the main. See Art. **12.**

(5) (*a*) The dry return main is carried above the water-line of the boiler, below the steam main.

(*b*) Branches from radiators are connected directly to the return from the foot of the riser. See Art. **13.**

(6) A light swing check-valve should be placed on the return near the boiler. See Art. **14.**

(7) A relief pipe should be connected to the steam drum and lead to the return drum. See Art. **16.**

(8) It should be so placed that the level of the water in the feeder will correspond with the desired line to be maintained in the boiler. See Art. **16.**

(9) The steam connection should be about one-half the capacity of the steam main; the water connection from one-fourth to one-half the capacity of the return main. See Art. **20.**

(10) The water is returned by the use of steam pumps, steam traps, or injectors. See Art. **23.**

(11) It is intended to control automatically the operation of the pump so as to maintain a fixed water-line in the returns that may or may not correspond with the water-line in the boiler. See Art. **29.**

(12) It should be below the trap to prevent the trap from being flooded when the steam pressure is low. See Art. **30.**

(13) Yes, so that the heat in the exhaust steam may be utilized to raise the temperature of the feedwater, thereby saving fuel. See Art. **32.**

(14) To prevent spray due to condensation of the steam from scattering over the roof and adjoining property. See Art. **32.**

(15) The oil can be removed by passing the exhaust steam through an oil separator. See Art. **35.**

(16) A pressure-reducing valve, by which the pressure on the heating system is reduced, is placed on the steam main. See Art. **42.**

(17) The water is automatically turned on by the melting of the fusible part of the sprinkler head. See Arts. **44** and **45.**

(18) When the temperature of the soldered parts reaches about 165° F. See Art. **47.**

(19) In the wet system, the pipes are under water pressure at all times, whereas with the dry system, an air pressure greater than that of the water is maintained in the pipes, thereby keeping closed a check-valve by means of which the water is prevented from entering the pipes until the heat of a fire melts the solder of the sprinkler heads. See Art. **56.**

(20) A 4-inch pipe. See Art. **56.**

(21) The feeder piping should have a by-pass so that when repairs are necessary the feeder may be cut out of service and the water fed directly from the city mains or

an overhead supply tank, as the case may be, to the boiler. See Art. **16**.

(22) It is necessary to provide for expansion of the connecting pipes between the boilers; also to arrange the boiler connections so as to insure an equalization of pressure and even water-line in the boilers; to provide the necessary valves for shutting off either boiler and operating the other independently. See Arts. **19** to **22**.

(23) For cutting apparatus out of service, as when repairs are necessary, without interfering with the continuous operation of the plant, by-passes should be arranged in the piping of auxiliary apparatus, some of which may advantageously be installed in duplicate. See Art. **23**.

STEAM-HEATING PIPE SYSTEMS

(PART 1)

(1) The main should pitch down from the highest point near the boiler, the entire length of the main. See Art. **1.**

(2) An overhead main runs nearly horizontal at an elevation higher than the radiator that it supplies. Steam is supplied through a vertical rising main. See Art. **1.**

(3) The dry return main is one that runs above the water-line of the boiler, while the wet return main is run below the boiler water-line and is filled with water at all times. See Arts. **1** and **13.**

(4) 966 B. T. U. See Art. **2.**

(5) The flow of steam is induced by the difference in pressure between that at the source of supply and that at the radiators. See Art. **4.**

(6) The frictional resistance offered by the piping, fittings, and valves, and also the accumulation of air in the system. See Art. **6.**

(7) The drainage of the pipe and the free movement of the pipe by expansion. See Art. **9.**

(8) Water hammer is caused by the collision of water with the fittings on the steam pipes. The steam carries slugs of water forwards at a high velocity. See Art. **11.**

(9) The dry return main should be one size larger, that is, 3 inches. See Art. **17.**

(10) $\frac{600 \times .8}{100} = 4.8$ sq. in. $= 2\frac{1}{2}$ in. Ans. See Art. **19.**

(11) The equivalent in direct radiation is $450 \times 2 = 900$ sq. ft. Referring to Table I, it is found that it will require a $2\frac{1}{2}$-in. pipe. See Art. **21.**

(12) Referring to Table III, it is found that the size of main required is 10 in. Ans. See Art. **23.**

(13) By Table IV, $\frac{300}{100} \times 1.01 = 3.03$ sq. in., or a pipe 2 in. in diameter. Ans. See Art. **26.**

(14) By referring to Table I, column 2, it is found that it requires $1\frac{1}{2}$-in. pipe. Ans. See Art **29.**

(15) $900 \times .5 = 450$ sq. ft. Ans. See Table II, Art. **23.**

STEAM-HEATING PIPE SYSTEMS

(PART 2)

(1) The steam and water flow in the same direction in the main; they flow in opposite directions and against each other in the risers. See Art. **3.**

(2) In the circulating main system the main is graded down from the boiler, and continued around the cellar in the form of a loop. It drops and connects to the boiler below the water-line. See Art. **5.**

(3) A light swing check should be placed on the return near the boiler. See Art. **5.**

(4) Comparatively small pipes can be used, as steam and water do not flow any great distance in the same pipe. See Art. **6.**

(5) They should be run in trenches of masonwork provided with a cover for easy access for repairs. A cock should be placed at the lowest point in the return to drain it. See Art. **7.**

(6) It is to prevent the steam in the dry return from by-passing or short-circuiting the return riser, and thus supplying the radiator with steam from its return end. See Art. **9.**

(7) In the one-pipe down-feed, or Mills, system the main is carried from the boiler directly to the attic or space above the top story, from which drop risers are taken to supply radiators located on the floors below. This system affords more headroom in the cellar than the up-feed system. See Art. **14.**

(8) The chief objection is that if either radiator valve is closed while the other is open, the radiator will fill with water, which will cause water hammer. See Art. **18.**

(9) In the two-pipe system, each radiator has two pipe connections to the boiler, one for the steam and the other for the water of condensation, so that the water does not interfere with the flow of steam, but flows in a separate pipe back to the boiler. See Art. **17.**

(10) In common-feed and separate-return systems, the radiators located on floors directly over each other are supplied with steam from one riser common to all. Each radiator is provided with a separate return that is connected to the main return below the water level of the boiler. See Fig. 17, Art. **20.**

(11) In the wet-return system, the return main is run below the water-line of the boiler; in the dry-return system, the piping is carried back to the boiler above the water-line. See Art. **22.**

(12) A water seal may be formed by making a trap in the return to prevent steam from entering the radiators through the returns. See Art. **25.**

(13) They should be connected with spring pieces to prevent the drip pipes from being broken off by the movement of the risers. See Art. **26.**

(14) In the one-pipe down-feed system, all the condensation from the radiators flows down the drop riser, the base of which connects to the return main; in the two-pipe down-feed system, all the condensation from the radiators is carried to the return main in the cellar by return risers separate from the steam drop risers. See Arts. **14** and **28.**

(15) Each radiator is incased separately. The upper part of the chamber containing the radiator communicates with the room to be warmed by means of a hot-air duct; the lower part of the chamber is connected by means of a cold-air duct to the outside atmosphere. See Art. **34.**

(16) In the semidirect system of heating, the base of each semidirect radiator is connected to the outside air by means of a cold-air supply duct provided with a damper to regulate the flow of air through the radiator. See Art. **36.**

(17) Air vents should be connected to a separate system of piping and carried to a convenient point of discharge, in order to prevent the foul air in the radiators from entering the rooms. See Art. **39.**

EXHAUST AND VACUUM SYSTEMS

(1) It is more economical to carry a back pressure on the engine. See Art. **1.**

(2) No. The steam should first be discharged into a separator to remove the water and oil or grease before the steam enters the heating system, because oil and grease reduce the heat-transmitting power of the radiating surface, and the decomposition of oily organic matter that would otherwise take place would produce offensive gases, extremely disagreeable if discharged through the air valves into the rooms. See Art. **4.**

(3) A live-steam connection should be made between the boiler and the heating main. The supply of exhaust steam may be controlled by hand, or a pressure-reducing valve may be used for automatic regulation of the steam supply, the latter method being the better. See Arts. **4** and **5.**

(4) A balance or pressure-equalizing pipe must connect the top of the governor to the steam-heating main, so that the pressure in the governor will always be the same as that in the heating system. See Art. **5.**

(5) Combination high-and-low pressure systems can be operated at any pressure above that of the atmosphere. The main return is connected to a return tank having a pipe opening to the atmosphere. Each radiator is provided with an expansion trap, as in Fig. 8, or siphon, as in Fig. 9. The water of condensation from the radiator passes to the

trap, and when sufficiently cooled the valve opens and the water flows into the return pipe, the air from the radiator escaping to the roof. The valve is then closed by expansion, and the process repeated. The boiler connection is provided with a reducing valve and by-pass, so that exhaust or live steam can be used. See Art. **9.**

(6) A vacuum, more or less perfect, is maintained in the system, thereby permitting the steam to be maintained at any degree of temperature suitable to the weather. If desirable during very cold weather, a vacuum system may be converted into a low-pressure system. See Art. **12.**

(7) It removes back pressure from the engine, thereby increasing its capacity to do useful work. See Art. **14.**

(8) Steam should be permitted to flow through the piping and radiators until all burrs, chips, sand, or cement are washed out of the system; otherwise, the thermostatic valve will become clogged by the dirt. See Art. **17.**

(9) The air vents of the radiators are piped to an exhauster that automatically removes air from the radiators. The exhauster is operated by a jet of steam or water automatically controlled by a regulator that is actuated by changes of pressure in the heating system. An air pump is sometimes used instead of a jet exhauster. See Art. **19.**

(10) A $\frac{3}{4}$-inch pipe. See Art. **24.**

(11) It consists of an outer and inner tube, the lower end of the latter being submerged in mercury, so as to form a seal to prevent air from entering the heating system after the air has been discharged. So long as the air pipe is cold and the pressure is above that of the atmosphere, the air will be forced through the mercury and out of the escape pipe near the base of the seal. After the air is expelled the condensation of steam in the heating system creates a partial vacuum therein. See Arts. **25** and **26.**

(12) It is necessary that all joints and valves shall be air-tight. See Art. **28.**

(13) A system of heating that is operated at a pressure lower than that of the atmosphere. See Art. **12.**

(14) A vacuum system is one in which a vacuum is mechanically maintained by means of pumps or other devices, whereas in so-called vapor systems a partial vacuum is created by the condensation of the steam within the radiators, special traps or seals being used to permit the air to escape but through which no air can enter the system. See Arts. **12** and **22.**

(15) The supply connection is made to a special regulator valve at the top of the radiator. The return is connected at the bottom of the radiator to a special union connection having a water pocket that prevents vapor passing from one radiator to another. See Arts. **31** and **32.**

(16) The system may be operated under a partial vacuum, thus securing the advantages of a low temperature in mild weather. See Art. **37.**

(17) $2{,}000 \times 4 = 8{,}000$ sq. ft. See Art. **1.**

HOT-WATER HEATING SYSTEMS

(1) On the amount of heat received on a given area of surface; the extent of heating surface in proportion to the volume of fluid; the place of application of the heat; and the conductivity of the fluid. See Art. **1.**

(2) By Table I and the rule in Art. **2,** $I = 200 \times (1.03889 - 1.00038) = 7.702$ cu. ft. Ans.

(3) By Table I and the rule in Art. **2,** $I = 40 \times 12 \times (1.035 - 1.00015) = 16.728$ in. Ans.

(4) The force that causes the water to circulate through the piping system. See Art. **5.**

(5) Water at 160° exerts a pressure of $\frac{60.991}{144} = .4235$ lb. per sq. in. for each foot in height. At 200° F., it exerts a pressure of $\frac{60.081}{144} = .4172$ lb. per sq. in. The available force is $(.4235 - .4172) \times 30 = .189$ lb. per sq. in. Ans. See Table I and Art. **8.**

(6) By attaching air valves at the highest points of the several parts of the system. See Art. **10.**

(7) To provide a receptacle into which the water may expand when heated. See Art. **12.**

(8) By Table I and the rule in Art. **2,** $I = 500 \times (1.0444 - 1) = 22.2$ gal. Ans. See Art. **13.**

(9) By the use of an expansion tank supplied with a ball-cock feed, and an overflow. See Art. **18.**

(10) The open system is that in which the water in the system is open to the atmosphere, while in the closed system the water is not open to the atmosphere. See Arts. 19 and **20.**

(11) Air and other gases are liberated from the water when heated. The air, being lighter than the water, rises to the highest point. See Art. **23.**

(12) The pipe should be graded upwards from the boiler at a uniform grade. See Art. **24.**

(13) It obstructs the flow of water through the pipes by reducing the sectional area of the current. See Arts. 25 and **26.**

(14) From the side of the main. If branches are taken from the top, a pocket will be formed in which air will collect and stop circulation. See Art. **28.**

(15) The water flows to the radiator through a single pipe without branches, and returns to the boiler through another pipe. See Art. **30.**

(16) The general direction of the current is through a large flow main and return main; these two mains are joined by branches on which the radiators are located. See Art. **31.**

(17) By Table I and the rule in Art. **2,** $I = 30 \times (1.031 - 1.0234) = .228$ ft. By the rule in Art. **36,** $V = 8.02 \times \sqrt{.228} = 3.828$ ft. per sec. Ans.

(18) Burrs formed in the end of the pipe should be removed, and all changes in the direction of the piping should be made with easy bends. See Arts. **38** and 39.

(19) The flow branches are taken from the top of the main, the return branches being connected to the bottom of the main. See Art. **41.**

(20) There is no opportunity for one radiator to rob another of its supply of water. See Art. **45.**

(21) To adjust and equalize the resistance in each circuit and branch, so that hot water will flow to each radiator with equal readiness. See Art. **52.**

(22) By Art. **55,** the size of pipe is $2 \times .76 = 1.52$ in., the nearest standard size being $1\frac{1}{2}$ in. Ans.

(23) By the rule in Art. **57,** $R = (.25 \times 325 + 80) \times .63 = 101.68$ sq. ft. Ans.

(24) By the rule in Art. **61,** and Table IV, $G = \frac{1,500}{5 \times 59.3} = 5.07$ sq. ft. Ans.

(25) By Table VI, a 4-in. pipe is required. Ans.

(26) By Art. **66,** size of main is $.16 \times \sqrt{900} = 4.8$, or 5-in. pipe. Ans.

(27) By Table X, a $1\frac{1}{4}$-in. pipe is required. Ans.

(28) By Table XI, a 2-in. pipe is required. Ans.

(29) By Table XII and Art. **80,** radiation is $\frac{\frac{600}{4} + 2,400}{3.25} = 784.6$ sq. ft. Ans.

(30) Allowing seventy diameters for each elbow and **T**, the length is $\frac{10 \times 70 + 4 \times 70 \times 2}{12} = 163$ ft. 4 in. Ans. See Art. **39.**

HOT-WATER HEATING APPARATUS

(1) No. Because they offer too much resistance to the flow of water. See Art. **1.**

(2) Flush fittings, as they offer the least resistance. See Art. **2.**

(3) In hot-water heating, the valves are required only to check or direct the current of water, which has but a small force or pressure. Steam valves must be made to close with sufficient force to be tight against a pressure. See Art. **7.**

(4) No. Because they offer too great a resistance. See Art. **8.**

(5) A small hole should be made through the valve, so that a slight circulation will be maintained in the radiator. See Art. **11.**

(6) It consists of a metal body or shell in which is placed a disk of metal having a lever handle by which it may be turned to any desired angle. The valve is used for regulating the flow of water. See Art. **12.**

(7) Steam draft regulators are operated by the change in the steam pressure. Hot-water draft regulators are operated by the difference in the temperature of the water. See Art. **26.**

(8) Connect an altitude gauge to the heating system at any convenient point. See Art. **30.**

(9) No valves should be placed in the pipe between the boiler and expansion tank. The tank and pipe should be carefully protected from frost. See Art. **34.**

CENTRAL-STATION HEATING

(1) About 10 lb. with live steam and 3 lb. with exhaust steam. See Art. **7.**

(2) The piping is laid in the street in a trench provided with brick manholes to give access to valves and special fittings, the piping being enclosed in a tin-lined wooden casing slightly larger than the enclosed pipe, around which there is thus provided an insulating dead-air space. Underdrainage of the pipe line is provided by using a 4-in. tile drain at the bottom of the trench. See Art. **8.**

(3) Because the life of wrought-iron piping used for conveying water of condensation is comparatively short, and the interest on the money invested in material and maintenance of a return line frequently would be greater than the cost of the water discharged to the sewer. See Arts. **10** and **12.**

(4) By special devices called variators, located in the pipe line at points 100 ft. apart. See Art. **17.**

(5) Because slip joints require more attention on account of the necessity for repacking them, and on account of the expense of providing manholes to make such joints readily accessible. See Art. **21.**

(6) Packingless gate valves with double gates, the valve being so made that when closed no steam can enter the valve body and when open no steam can escape at the gland. See Art. **23.**

(7) By the use of special fittings known as flanged angle joints. See Art. **24.**

(8) By means of what are known as street-corner specials and anchor specials, from which expansion takes place toward the variators. The street-corner specials are located at the street corners, the anchor specials being placed in the pipe line midway between the variators. See Art. **25.**

(9) At anchor specials and variators, because these fittings are fixed in position, thereby obviating the possibility of a break or leak in the service pipe at the point of connection; such breaks might otherwise result from the movement of the steam main due to expansion and contraction. See Art. **27.**

(10) The use of round tin-lined wooden casing, providing a 1-in. dead-air space around the enclosed pipe, is much favored. Sectional salt-glazed earthenware conduit is also used as a protection to the insulating material, such as granulated cork, asbestos, etc., by which the pipe is sometimes surrounded. See Arts. **28** to **32.**

(11) A regulating or pressure-reducing valve is placed in the house-service pipe. See Arts. **38** and **39.**

(12) To cool the water of condensation from the radiators to such a temperature that the water will not injure the sewer into which it is discharged. Cooling coils are also made to serve as auxiliary indirect radiating surface for warming fresh air for ventilation. See Arts. **41** and **42.**

(13) According to Table II, Art. **43,** the coil factor corresponding to a condensation temperature of 80° is .14; then $.14 \times 900 = 126$ sq. ft. Ans.

(14) By a condensation meter, through which the water of condensation is passed on its way to the sewer. See Art. **45.**

(15) Actual measurement of the steam condensed, as by a condensation meter. See Arts. **48** and **49.**

(16) According to Table IV, the factor corresponding to a length of main of 1,500 feet and a steam pressure of 5 lb. is .0051; then, $.0051 \times 26{,}000 = 132.6$ sq. in. area,

which corresponds most nearly to a pipe having a diameter of 13 in. Ans. See Art. **50.**

(17) By means of centrifugal, or other, pumps, which maintain the head required to cause the necessary rapidity of circulation. See Art. **54.**

(18) One in which the circulating pumps take their supply from an open tank into which the return water from the distributing pipes flows by gravity. See Art. **58.**

(19) Those in which the distributing pipes form a closed circuit, of which the circulating pump is an integral part, the delivery end of the pump being connected to the outgoing distributing main, while the suction end is directly connected with the return main. See Art. **58.**

(20) Substituting known values in the formula given in Art. **60,** $R = \frac{3,300}{100} + \frac{350}{10} + 64 = 132$ sq. ft. Ans.

(21) A choker is usually a perforated disk inserted in the return line of the indoor piping system. Its purpose is to control the amount of hot water supplied to the building from the street main. See Art. **61.**

(22) According to Table VII, a $\frac{1}{2}$-in. choker at the given temperature drop will supply 1,050 sq. ft. of direct radiation; the factor for a pressure difference of 10 lb., as given in Table VIII, is 1.36; hence, $1.36 \times 1,050 = 1,428$ sq. ft. Ans. See Art. **61.**

(23) By thermostatic regulation in each building served, and by station regulation through variation of the speed of the pump, the operation of which is automatically controlled by thermostatic apparatus. See Art. **64.**

(24) Three; the single-main closed-circuit system; the double-main open-circuit system; and the double-main closed-circuit or balanced-column system. See Art. **65.**

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Note.—All items in this index refer first to the section and then to the page of the section. s, "Air piping 35 16" means that air piping will be found on page 16 of section 35.

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